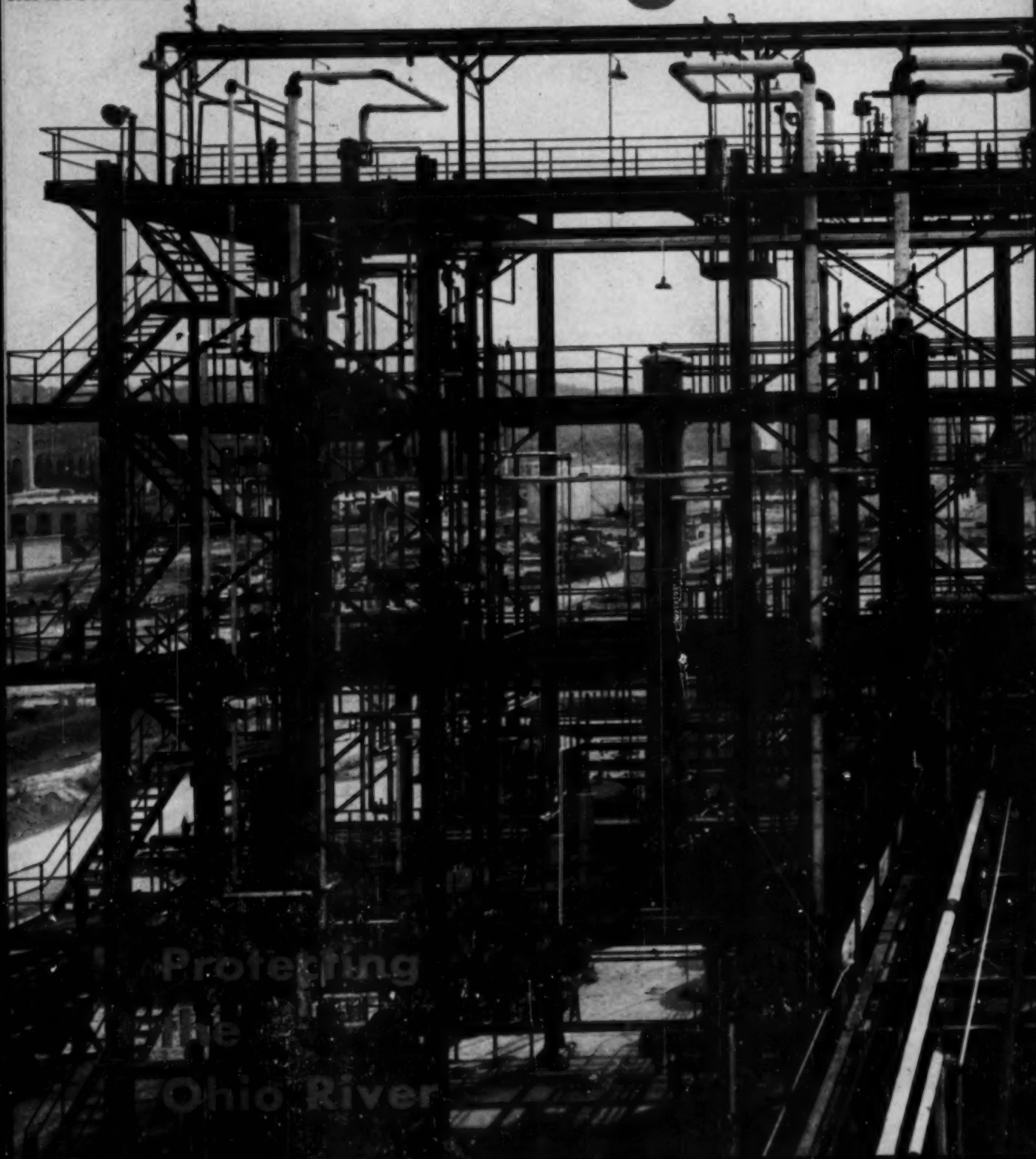


# Chemical Engineering Progress

MARCH 1954

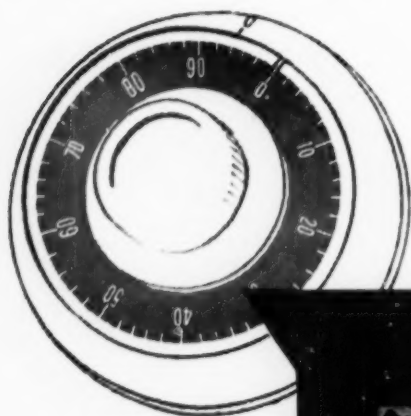


Protecting

the

Ohio River

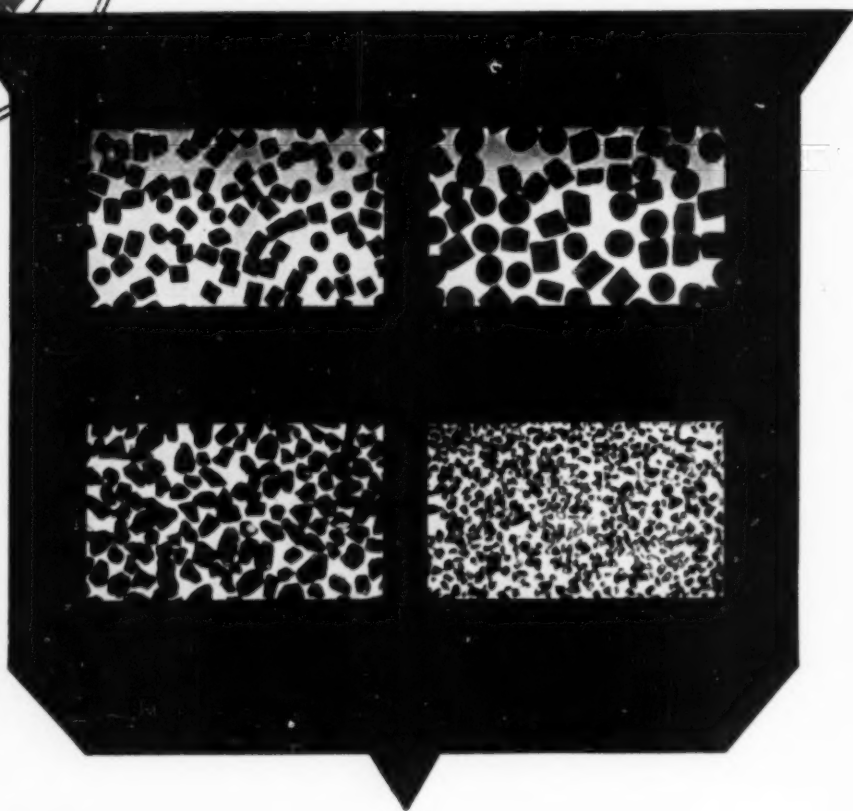
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# Chemical Engineering Progress

MARCH, 1954

Volume 50, No. 3

Editor: F. J. Van Antwerpen

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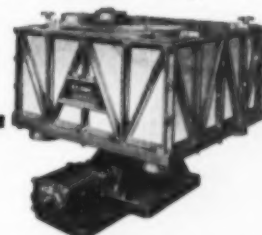
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Advertising Manager: L. T. Dupree

The cover this month shows part of the Carbide & Carbon coal-hydrogenation plant at Institute, W. Va. At the left is the waste-treatment section described in "Recovery of Phenolics from Waste Effluents" by on-location authors Edmonds and Jenkins. Aqueous discharge (stripped of phenolics) goes to a settling basin (not shown) and then into the Kanawha River, which flows only a few miles before joining the Ohio. What would otherwise be an annoying pollution problem is thus averted through the application to the effluent, of the same degree of chemical engineering interest as was afforded the main product stream.

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## LETTERS TO THE EDITOR

### An Old Army Game?

Recent articles on the "National Survey Questionnaire" dealt with the relationships of the chemical engineer to industry and public. An equally important subject, especially to younger members of the profession—the military and the chemical engineer—was not investigated.

I noticed that the national meeting to be held soon in Washington will include a talk on one phase of that subject, the Scientific and Professional Personnel" (SPP) operation of the Army. May I quote a sentence from the abstract on the talk:

"With a limited national supply of manpower, the effective utilization of technically trained personnel is of great importance." The implication is that the chemical engineer graduate inducted into service would, after his basic training, be assigned to a position where his knowledge could be put to use. However, he is not considered eligible for a SPP rating until he has one year of experience behind him; without this rating he is likely to be assigned to something entirely unrelated to the engineering field. The electrical and mechanical engineer graduate, on the other hand, is given the SPP rating automatically, no experience required.

Why the distinction between the professions?

HERBERT H. LUBITZ

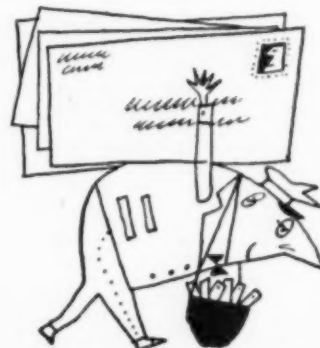
New York, N. Y.

### Education vs. Engineers

Your editorial on "The Clash of Symbols" in the February issue of *Chemical Engineering Progress* is one of the first public admissions that has come to my attention to the effect that education is being so rapidly replaced in the United States by training for "dollar chasing."

All my life I have been associated almost exclusively with the so-called "Engineering Profession." I have found these "engineers," with few exceptions, to be incapable

(Continued on page 10)

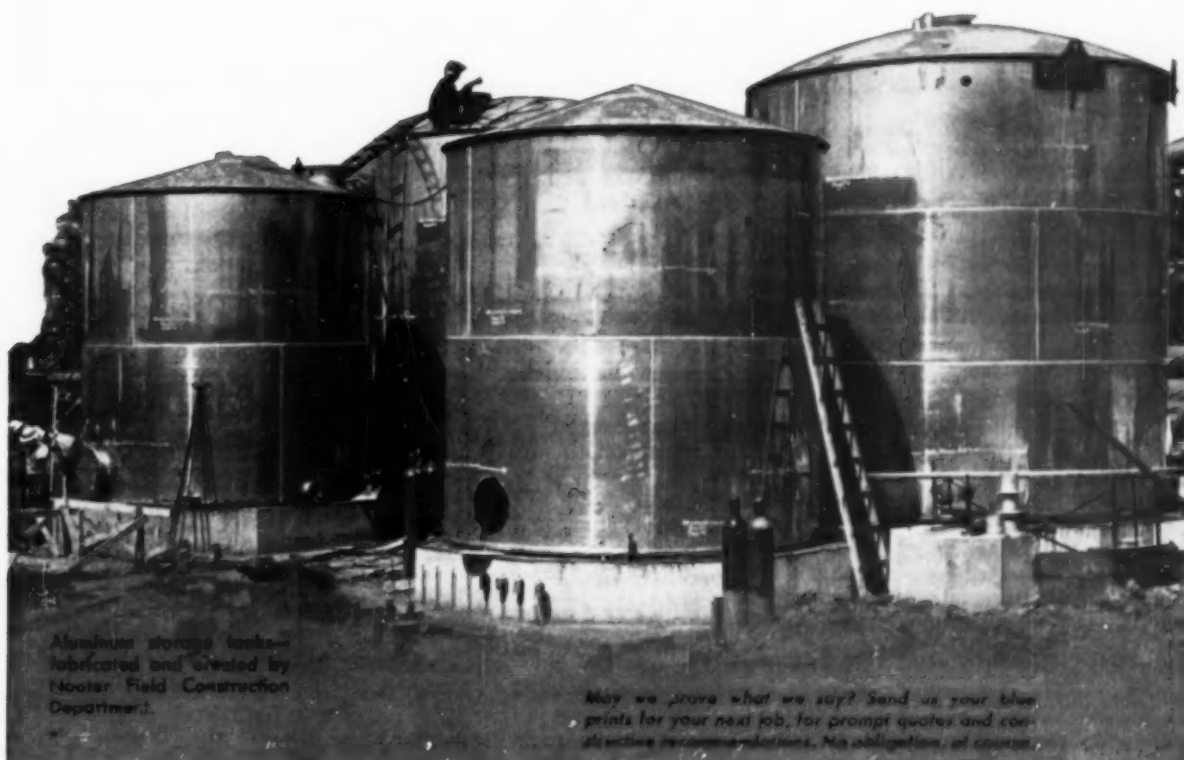


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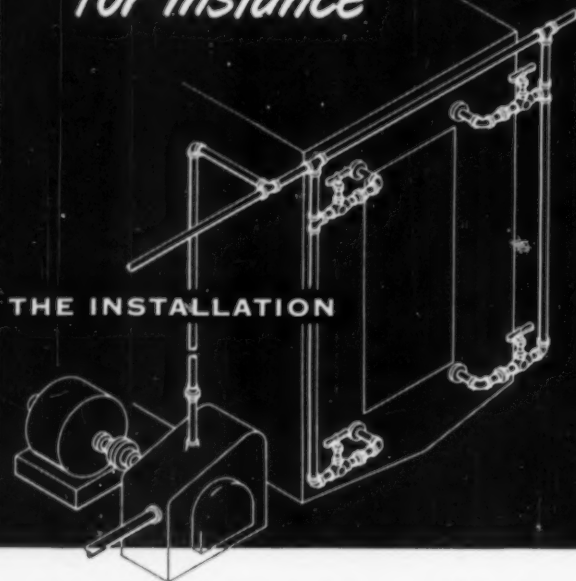
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**SAFE** from corrosion

**SAFE** from contamination

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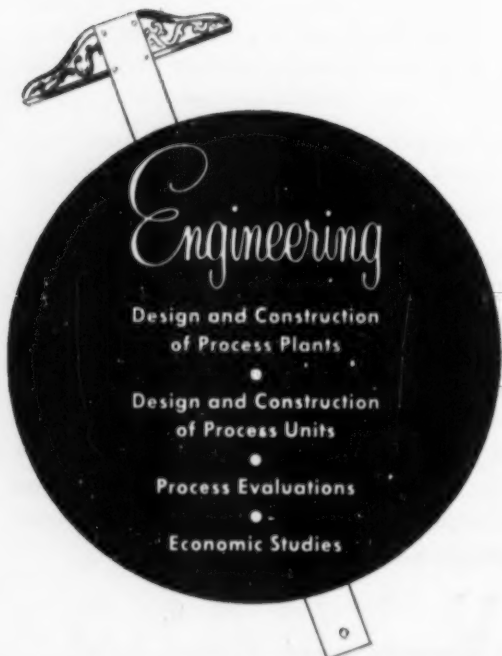


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## LETTERS TO THE EDITOR

(Continued from page 4)

of thinking outside the field of their "profession." Education is to them unknown territory. Arm-chair plumbers, machinists, ditch-diggers, etc., have been designated in recent years as "engineers," the title having been usurped from the men who used to run donkey boilers or steam locomotives. To have designated it as a profession, comparable to the field of law, etc., has been absurd, but has been a natural consequence of the prevalent desire to avoid manual labour, and to make the accumulation of money the supreme object of life.

I am surprised and deeply gratified to learn that somebody, either with some education or with some respect for education caused you to lose the battle for abolishing the use of the Greek alphabet in engineering. Why not try to teach the people who use it—professors, students or anyone else—to write it correctly and legibly? Of course many "engineers" can't write good English nor spell it, correctly, but maybe it would not be too difficult to teach them the Greek alphabet.

WILLARD B. SAVARY

Harrison, N. J.

[Education is an elusive quantity; it is hardly guaranteed by a knowledge of the Greek alphabet. We doubt that engineers or mathematicians will stop using Greek letters, but the fact remains that the letters are used as symbols and we need more symbols.—Ed.]

### Accredit High School?

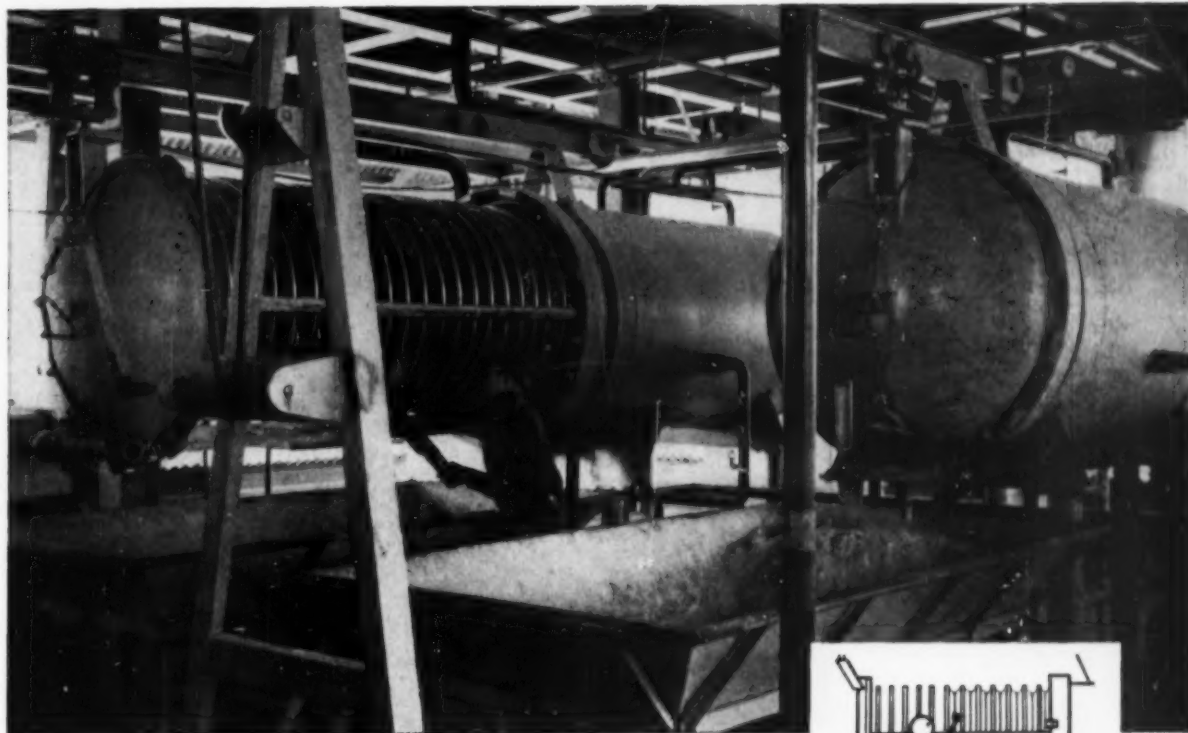
You expressed the desire for comments from your 17,000 readers. Let's hope they do not swamp you all of a sudden.

Here is mine for what it is worth. And it is directed incidentally also at Dr. Nichols whose talk in Pittsburgh impressed me very much. He told us of an impending change of publication policy. You will eventually have a magazine covering general and engineering topics and transactions covering the gruesome details. Frankly, I like it that way. I think Mechanical Engineering is one of the best-balanced magazines and you will be approaching or even surpassing it with the new policy.

Your article: "Life at an American University" by E. J. Cullen was very enlightening. His reference to the two lost years at the American colleges struck a chord with me. The A.I.Ch.E. pioneered the accrediting of colleges and is now still the important factor together with the ECPD. I have been wondering for years whether these two bodies could not do something to relieve the load of the colleges and forcing it on the high schools which do less and less for the future college students at a terrible waste of young

(Continued on page 16)





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☐ Have representative call ☐ Send Catalog NC1-53

Name \_\_\_\_\_

Title \_\_\_\_\_

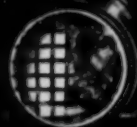
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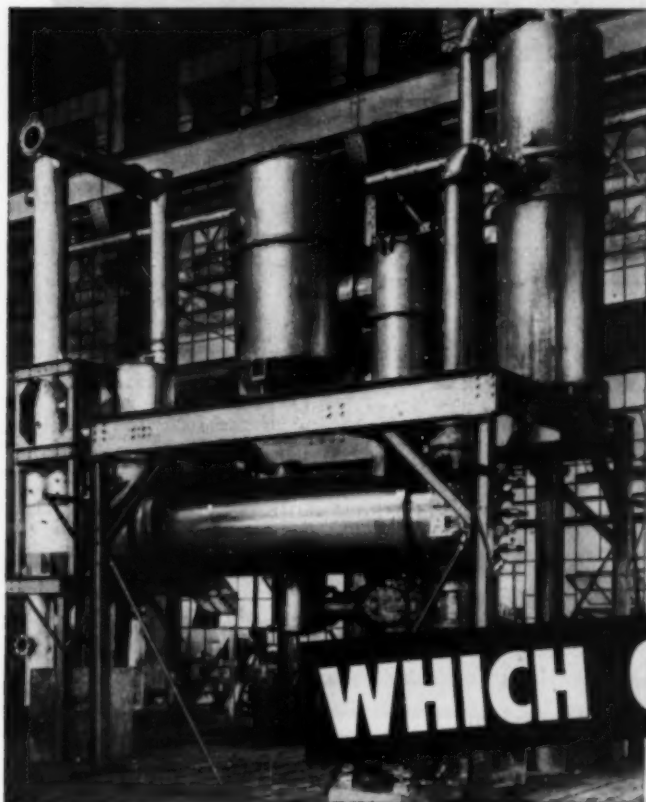
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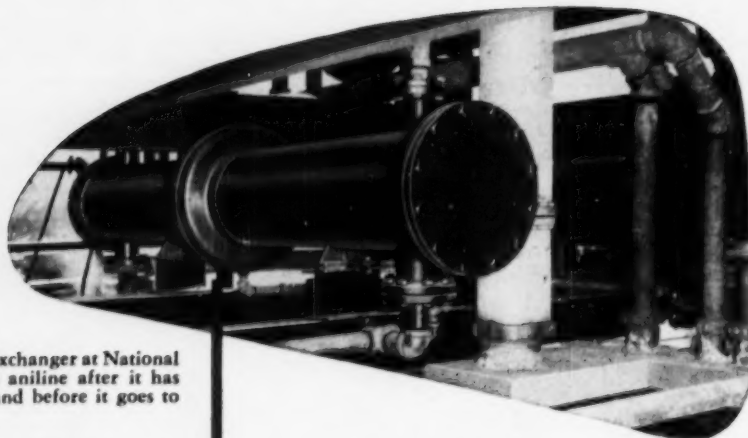
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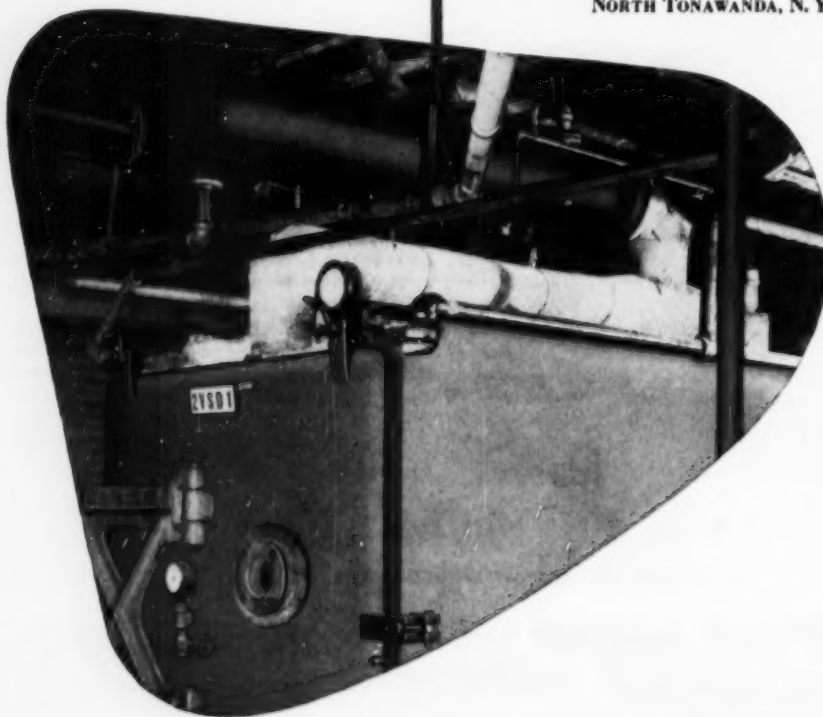




• ADSCO Heat Exchanger at National Aniline sub-cools aniline after it has been condensed and before it goes to storage.

## WHERE A HEAT EXCHANGER MUST BE GOOD

• ADSCO Heat Exchanger (insulated) above vacuum drier at National Aniline condenses organic acid vapor in tubes with water or brine in shell. Exchanger equipped with shell expansion joint.



The ADSCO Heat Exchangers shown on this page are installed in the Buffalo, N. Y., plant of the National Aniline Division of Allied Chemical & Dye Corporation. The manufacturing processes of National Aniline require engineered equipment of the highest caliber. . . . ADSCO, in business since 1877, offers the chemical processing industry a complete line of carefully-engineered heat exchangers built to customers' specifications or to our recommended designs. Inquiries are cordially invited.

### AMERICAN DISTRICT STEAM COMPANY, INC.

GENERAL OFFICES  
NORTH TONAWANDA, NEW YORK

PLANTS  
NORTH TONAWANDA, N. Y., AND RICHMOND, CALIF.



EXPANSION  
JOINTS



TRAPS

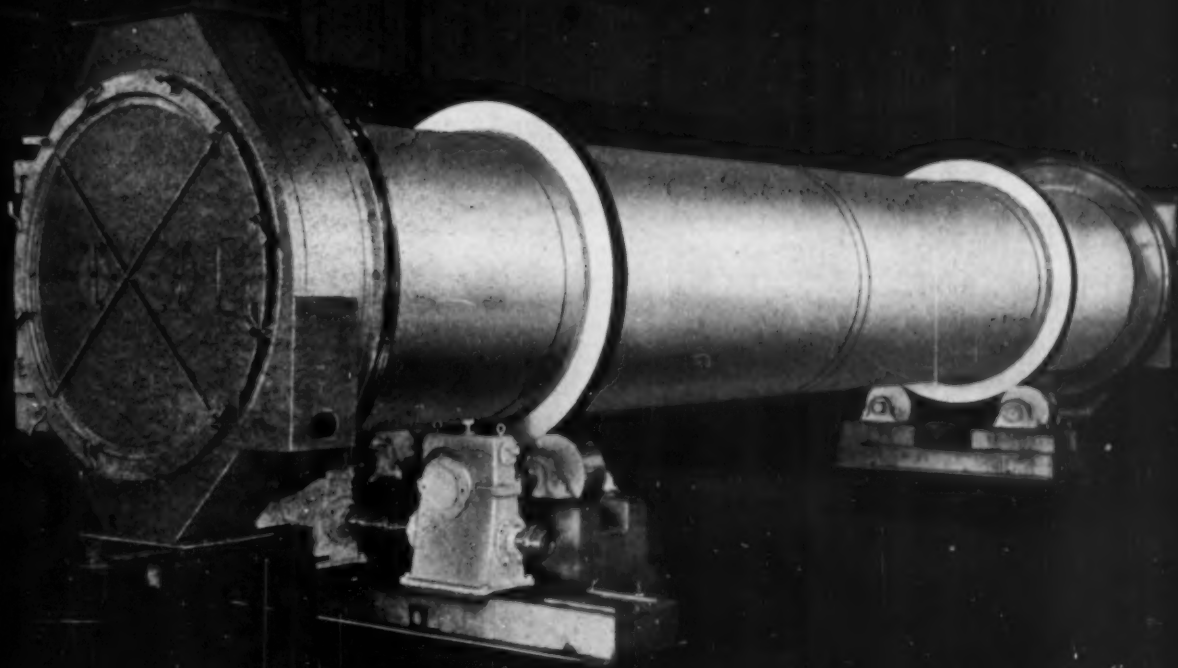


STRAINERS



SEPARATORS





**stainless steel**

# Plastics Dryer



Labyrinth Seal on 60" x 32' 0" Stainless Steel Plastics Dryer showing the Mirror-like Finish on the Shell and Flights.



Special Steam Jacketed Batch Dryer showing Dustless Discharge to Screw Conveyor and Condenser where Fines are Reclaimed from Vapors.

**60" x 32' 0" stainless steel dryer with all interior surfaces polished to mirror finish prevents color contamination—and spoilage—between different batches of a well known plastic.**

● This is probably one of the most costly direct heat rotary dryers ever built. Even the feed and discharge breechings and inspection doors are of stainless steel. Inlet air used for drying is filtered. Discharge air is passed through a stainless steel cyclone dust collector. Fabricated in our shops, this unit typifies Bartlett-Snow's ability to design and build equipment for even the most exacting operating and service requirements.

DESIGNERS

ENGINEERS

**BARTLETT  
-SNOW**  
CLEVELAND 5, OHIO

FABRICATORS

ERECTORS

*Dryers • Coolers • Calciners • Kilns*

*"Builders of Equipment for People You Know"*

**VERTICAL  
PUMPS  
WITH  
NO SUBMERGED  
BEARINGS  
FOR PUMPING  
ABRASIVE  
CORROSIVE  
SLURRIES**



2" Dual Discharge  
Pump for pumping  
molten caustic slurry.

Cross section of  
Dual Discharge  
Pump.

This rugged type of service calls for advanced design: — extra heavy shaft, double-ported casing to equalize the side thrust of the impeller, and tough abrasion-corrosion resistant alloys. The dual discharge pump illustrated here incorporates these features and dispenses with bearings or packing below the cover plate where they would be in contact with the liquid.

Difficult pumping problems, particularly in the process industries, have been our specialty for ninety-one years. Perhaps we can be of help to you. Write us — no obligation.

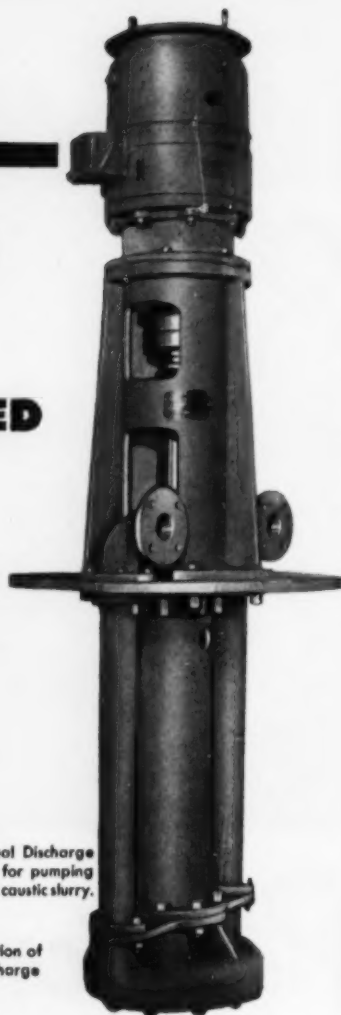


Write for Bulletin  
203-6 for complete  
summary of acid  
and chemical pump  
data.

**LAWRENCE  
PUMPS  
INC.**



375 MARKET STREET, LAWRENCE, MASS.



**LETTERS TO THE EDITOR**

(Continued from page 10)

brain power. As a father, I could be a lot more outspoken having had the benefit of both the European and American education (Dipl. Ing. and M.S.).

JACK M. NOY

Langeloth, Pa.

**No Drought in Iowa**

"Horn of Amalthea," page 20A in the January issue, speaks of the water problem. The need for collecting data on water resources is basic for further development of many industries. In contrast to New Jersey where sub-surface water is hot and scarce, here in Iowa the drillers have no difficulty in locating 400 gal./min. wells of 53° F. water with the bench at 40 to 50 ft. Eight of these wells in this community supply ample water of low hardness for residence and industrial use. There are probably many more areas where good water is plentiful at the present time.

RAY H. JEBENS

Charles City, Iowa

**More on Tappi**

I have read the letter by Mr. Kohlins in the December, 1953, issue of Chemical Engineering Progress concerning the service by TAPPI to its members as compared to A.I.Ch.E. I, too, am a member of A.I.Ch.E. and TAPPI. Over the past twenty-five years in which I have been a member of TAPPI the growth has been indeed interesting during this period and prior to that. The books, methods, data sheets and other material which Mr. Kohlins cites as being distributed by TAPPI gratis have not been worked up over-night. They have been the practical outgrowth of numerous company memberships (now some 400 at \$200 each); the hard, consistent and guided committee work of professional men in the industry; and the fact that the Pulp and Paper Industry is in itself a closely knit group.


Mr. Kohlins has a very good point of view, and I hope that this whole subject will be reviewed—How can A.I.Ch.E. render greater services to its members so that both the profession and industry will benefit?

JOHN B. CALKIN

Foster D. Snell, Inc.  
215 West 15 Street  
New York 11, N. Y.

**EDITOR'S NOTE**

Last month we garbled our own words for a change. The Editor's explanation to the letter by Mr. Ademino should have stated that the figures for the earnings of the doctors, lawyers, and dentists were released by the Bureau of Labor Statistics and therefore have an aura of authenticity. Bureau figures for the earnings of chemical engineers issued later were not far out of line with the survey reported in the August, 1952, C.E.P.



Those MARLEY fans  
· sure move a lot of air!

...and they will  
keep on doing it!



... that's because Marley multi-blade aluminum fans are engineered specially for cooling tower application—specifically, for Marley cooling towers. The true air foil blade design, based on years of research and wind tunnel testing, was selected as the most efficient for the range in air velocities and pressures found in various types of cooling towers. The twist and taper of the wide, sturdy blade is designed to provide constant velocity from hub to tip. By using six to twelve blades, depending upon fan diameter, Marley fans operate more smoothly and quietly.

Another reason Marley fans move a lot of air is that they operate in Marley Laminated Fan Cylinders, developed to complement the performance of this particular fan. Marley fans, air delivery cylinders and Geareducers are engineered as complete functional units, assuring the balance necessary to attain top fan efficiency.

Durability and strength are important, too. These are achieved by utilizing the newest casting techniques and an aluminum alloy selected for its castability, strength and corrosion resistance. Every dimension from shank to tip is more than ample for any operating load encountered.

For further details write for Bulletin No. CF-54 or contact your nearest Marley representative in any of fifty major cities.

**The Marley Company**

Kansas City, Missouri

Founder Member  
Cooling Tower Institute



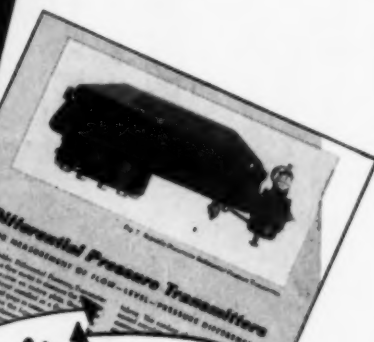
*Yours*  
For the Asking—

## New DATA BOOK

about **ALL**  
**REPUBLIC**  
Pneumatic Transmitters  
for Measuring  
**FLOW • PRESSURE  
LEVEL • DENSITY**

### REPUBLIC Pneumatic Transmitters have these **FEATURES**

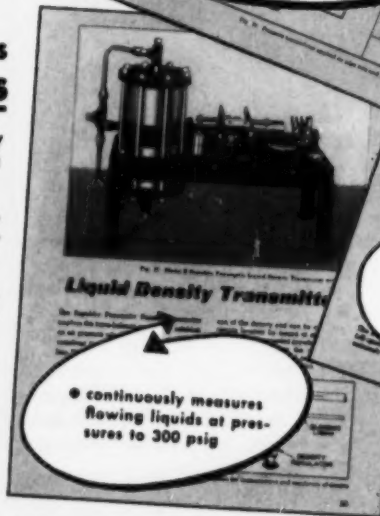
- **ACCURACY** to 1% and in many cases  $\frac{1}{2}$  of 1% of maximum range scale
- **RANGE EASILY CHANGED**, reversed, suppressed or compounded
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- **UNAFFECTED** by vibration, ambient temperature variations and changes in line pressure, air supply pressure and fluid density



- for flow and other differentials as small as 0.06" H<sub>2</sub>O and as large as 0-750 psi
- can handle most corrosive fluids



- for pressures to 2000 psig
- ruggedly built, easily maintained



- continuously measures flowing liquids at pressures to 300 psig



- for open or closed tanks
- can also measure liquid-to-liquid interface

• SEND FOR DATA BOOK 1004 TODAY—NO OBLIGATION

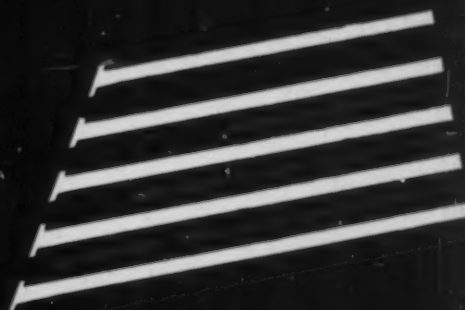
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## **petrochemical processes**



Foster Wheeler has been actively associated with both the petroleum and chemical industries for over 30 years and has designed and constructed many individual petrochemical process units as well as complete chemical plants.

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now "on stream"

**the FOSTER WHEELER  
process for -**

# **ammonia synthesis**

**TEXACO PARTIAL OXIDATION** The new non-catalytic oxidation process for the low-cost conversion of hydrocarbons (gaseous or liquid) into Carbon Monoxide and Hydrogen. This process, now in commercial operation, represents the latest development in synthesis gas technology.

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Two Ammonia producing plants recently placed "on stream" and four more are in various stages of design and construction. These six plants have a rated capacity of **1000 Tons per day.**

Write for **Bulletin O-54-1**

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**Solvents can't start trouble**

... because a **Chempump**\* has no seal!

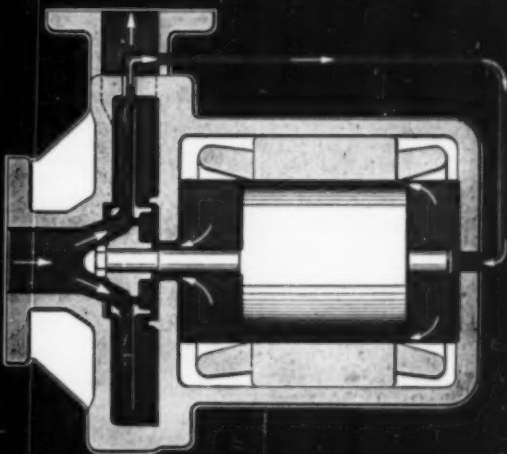
Because there is no seal, trouble just doesn't have a chance to start in a Chempump. There are no mechanical seals to fail. No stuffing boxes to pack or adjust. No lubrication required. The combined rotor and impeller assembly is the only moving part and it can be replaced quickly and easily... without breaking piping connections.

You'll have no fluid losses from a Chempump either. Toxic, hazardous or valuable fluids can't escape. Besides protecting your plant and personnel, the enclosed design protects the fluid from external contamination... an important consideration for vacuum applications with flooded suction.

The Chempump is available in  $\frac{1}{4}$ ,  $\frac{3}{4}$ , 1, 2, and 3 horsepower sizes... open or enclosed impeller. Standard materials are cast iron, 300-series stainless steel or Monel. Special materials available on request.

For complete information and performance data, clip the coupon and send it in.

The Chempump is a new concept in pump design that completely eliminates all seals and stuffing boxes... the source of about 90% of pump troubles whenever corrosive, volatile, toxic, radioactive or other hazardous liquids are being handled. The Chempump is totally enclosed... motor and all the fluid being pumped circulates freely through the rotor chamber of the motor. The motor and its windings are isolated from the liquid by a corrosion resistant non-magnetic alloy cylinder housing in the air gap. The rotor is hermetically sealed to the stator and is supported by



**Chempump**

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\*Chempump is the result of experience gained from over 15,000 field installations on seal-less pumps.

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Please send complete Chempump performance data.

Name..... Title.....

Company.....

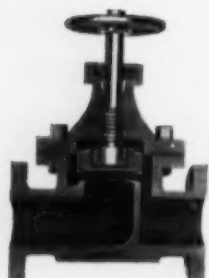
Address.....

# Buna N handles both!

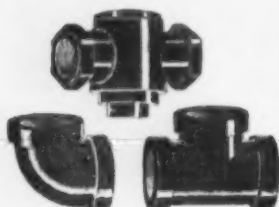
**VANTON Buna N and Natural  
Hard Rubber Pumps, Valves,  
Pipe and Fittings . . .**



Centrifugal pumps



Globe, angle & Y valves



Pipe and fittings

handle a variety of tough corrosives without danger of rust or contamination. The new Buna N line resists most inorganic acids, alkalies, salts and fumes, as well as many organic chemicals . . . at temperatures up to 225°F.

## Buna N and Natural Hard Rubber

**Centrifugal pumps** with open or closed impellers ranging in capacity from 20-130 gpm, head to 100 feet, suction 2" and discharge 1½".

## Buna N and Natural Hard Rubber

**Globe, angle and Y valves** with metal reinforced stems and discs, and readily renewable seating surfaces of soft rubber. Float valves, foot valves, strainers and check valves. Sizes range to 4".

## Buna N and Natural Hard Rubber

**Pipe & fittings**—plain or threaded. Tees, elbows, couplings, crosses, bushings, flanges, unions, cocks, plugs, and caps. Full flow capacity and high strength. Working pressures of 50 psi.

Bulletin HR tells the full story. Write today for free copy.

VANTON corrosion resistant products for fluid handling include flex-i-liner plastic pumps, polyethylene valves and PVC pipe and fittings. Bulletins on request.



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**PUMP & EQUIPMENT CORP.**  
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NOTED AND QUOTED



## Science a Factor in Our Spiritual Life

It seems to me that we often underestimate the true social and cultural values of industrial science and technology. We speak as if our modern progress in engineering had merely given us new tools and physical comforts. But the civilizing influences, even the spiritual powers of our people, have been strengthened and broadened as a result of our progress in applications of science. . . .

It is surely no mere coincidence that the period of growth of our school system and the growth of all our colleges and universities is precisely the period of our greatest gains in industrialization. Our hope of a general school system was not possible until we had mechanical power to replace hand power. Until then the young people could not be released from daily work on farms and in mills to attend school. Today we have some 34 million young people in our schools, easily ten times the number that we had fifty years ago. Our colleges and universities have ten times the total population they had in 1900. This is a cultural value added to our common weal because we have acquired new tools, new methods, new economic organizations, and a new national economy. All of these, to a considerable part, are derived from the improvement in our knowledge and use of technology.

. . . Industry should pay for its additional scientific and engineering brains just as it now pays for its other facilities for doing business. Industrial leaders must learn to understand that contributions in support of engineering and scientific education should be a direct charge against the business, not a charitable gift.


Horace P. Liversidge  
Address to A.S.E.E.

## Authors, Be Brief

When it comes to authors the editors realize that they are dealing with a very personal matter in suggesting condensation of a paper over which much time and thought have been expended. To anyone who has gone through the hard work of writing an article, the suggestion of another person that it might be just as good, or even better, if consider-

(Continued on page 26)





# Twin Staynew

LIQUID FILTERS *on the job*  
*in Gustin-Bacon Manufacturing*  
*Company's Kansas Plant*

Treated water used to cool transformers, busbars, bushings, and bushing terminals in the Gustin-Bacon Manufacturing Company's plant at Kansas City must be kept free of all foreign matter to insure uninterrupted around-the-clock operation.

Since the installation of these giant bronze fitted ELS Liquid Filters in the circulating cooling water system, down time due to cooling tube and orifice stoppage has been eliminated.

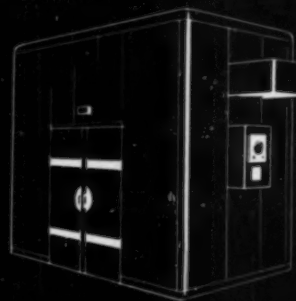
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PROTECTION  
STAYNEW FILTERS

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ALL TYPES OF FILTERS FOR EVERY INDUSTRIAL NEED

# "NATIONAL" PROVIDES THE *Economical Solution* TO *Any Drying Problem!*



No matter what your product may be, it can be dried or otherwise processed at a lower cost per pound or other unit, in one or more of the various types of "NATIONAL" equipment.

High-speed production; maximum effective use of the drying medium under finely adjusted control; adaptability to existing plant conditions and future expansion; and the assurance of long, trouble-free operation are among the important reasons why "NATIONAL" machines are being erected in more and more chemical plants throughout the United States and in other countries.

## NEW "P-4" CONSTRUCTION:

The result of a radically new approach to simplified Dryer construction, "P-4" Construction provides a precision-built, prefabricated structure, with trussed-and-tensioned insulated panels. It assures a more rigid, durable machine, with installation time in your plant reduced as much as 50%.

## "ADD-A-UNIT" DESIGN

This unique accomplishment of "NATIONAL" engineering provides alternatives which are both practical and economical—(1) simplification of the initial installation based on present requirements; (2) maximum adaptability to step-by-step future expansion.

## OTHER SPECIAL FEATURES

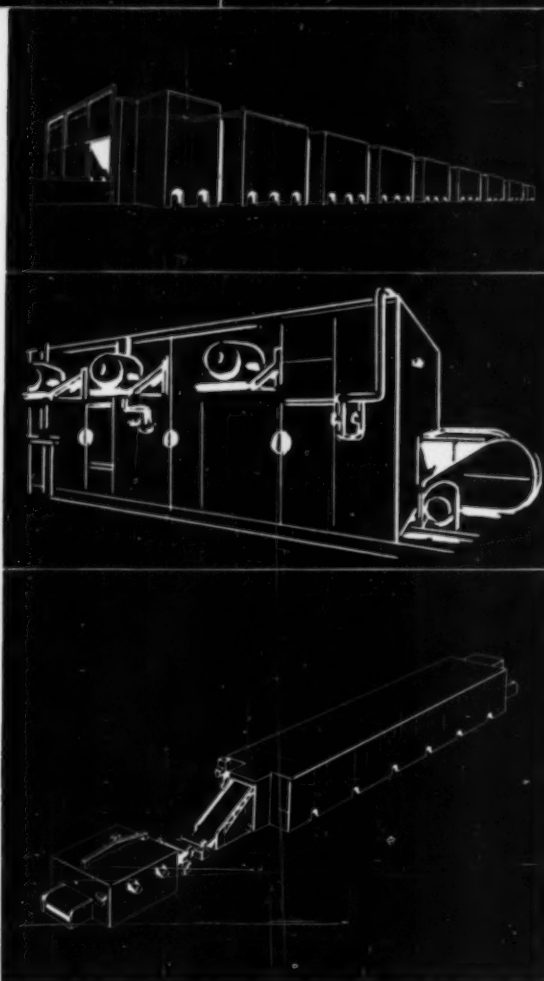
Patented Super-Power Fans, made in our own shops to specifications developed through years of industrial drying experience.

Patented Indexing Orifices, Turning Vanes and other devices and arrangements assure unequalled versatility and precision in air distribution and control.

The heat source may be steam, gas, oil or other medium. "NATIONAL'S" special gas firing systems, *Factory Mutual approved*, provide controlled uniformity of high temperatures; absolute safety; and lower maintenance costs.

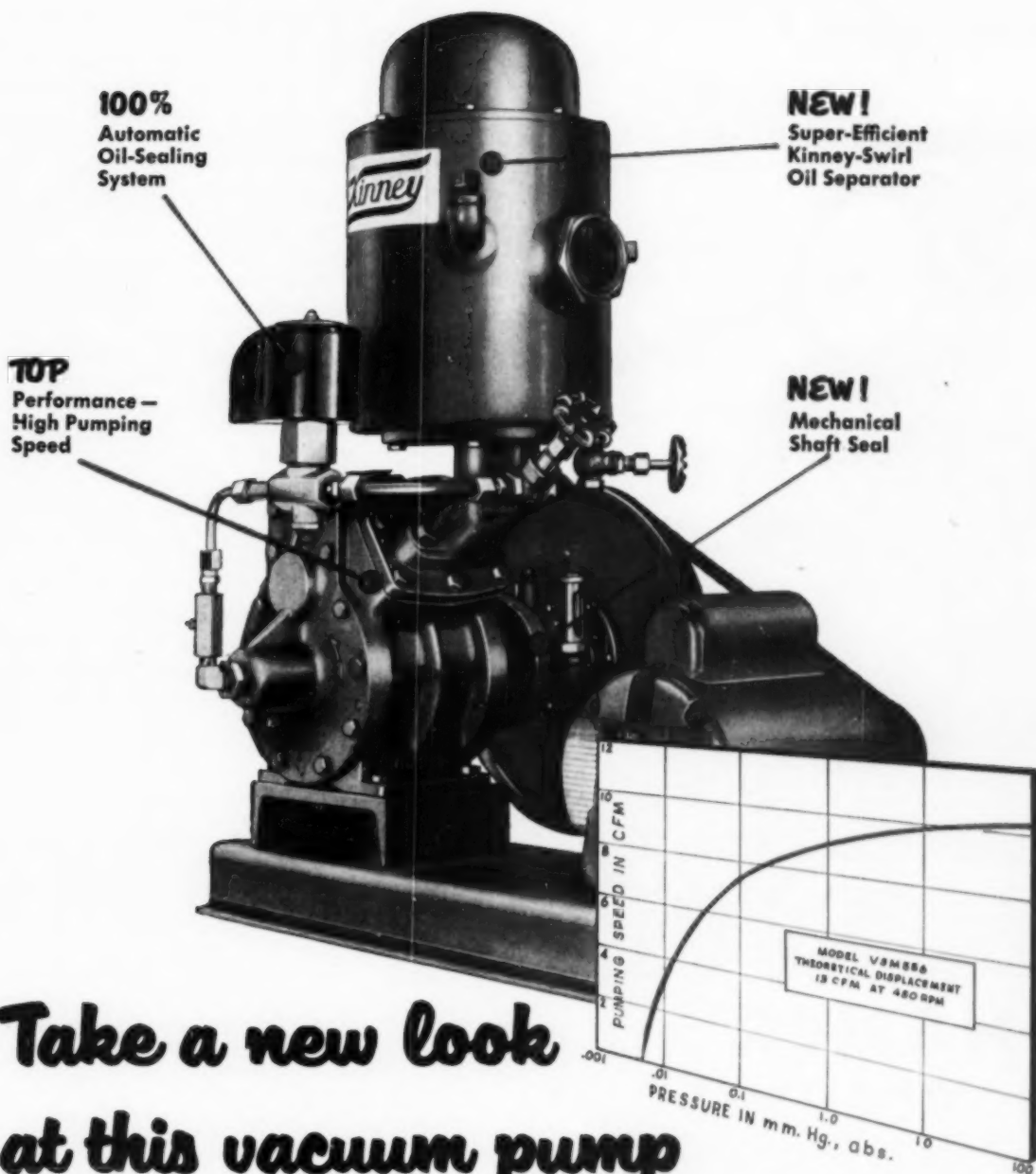
\* \* \*

When you have a *new* product which presents a drying problem, or if you want to improve your present drying processes, call "NATIONAL" Engineers for consultation. It is your surest way to improved production and lower over-all costs.



Illustrated above are typical "NATIONAL" Dryers for the Chemical Industry. From top to bottom: Cross-circulation type Truck Dryer; large multiple-unit Tunnel Dryer; single-apron Conveyor Dryer; large multiple-unit Tunnel Conveyor Dryer.

THE  **DRYING MACHINERY CO.**  
LEHIGH AVENUE and HANCOCK STREET  
PHILADELPHIA 33, PENNA.



## Take a new look at this vacuum pump

It's Kinney Model VSM 556 . . . 13 cubic feet of free air displacement. Model VSM 556 is now serving in many of the nation's foremost vacuum processing systems. Look at its outstanding features — and at its high pumping speed. Check your own vacuum requirements . . . and then come to Kinney for the most vacuum pump for your money. Send coupon for complete details.

### KINNEY MFG. DIVISION THE NEW YORK AIR BRAKE COMPANY

3548 WASHINGTON STREET • BOSTON 30 • MASS.

- ☐ Please send Bulletin V-51B describing the complete line of Kinney Vacuum Pumps.
- ☐ Please have your vacuum engineer call at our plant.

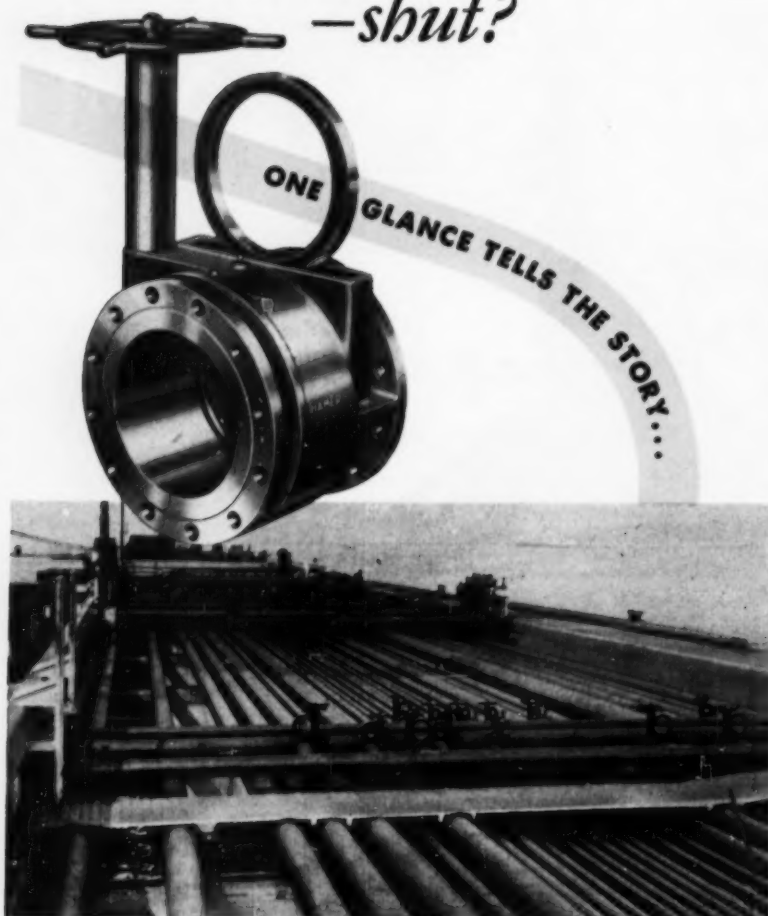
Name

Company

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*Lines open?*  
—*shut?*



## HAMER *Visible Shut-off* LINE BLIND VALVES

### HAMER Plug Valves

Standard dimensions . . . easy to substitute in existing installations. There's a HAMER non-stick Plug Valve for any requirement.



Don't guess—With the Hamer Line Blind Valves you know instantly at a glance which lines are open and which are shut. If the open end of the spectacle plate is up, the line has a permanent, positive shut-off . . . blank end up indicates a round, full open line. And Hamer Line Blind Spectacle Plates are easily visible from a distance . . . no need for individual valve checking. An enclosed plate slot on the Hamer Valve eliminates product waste while spectacle plate is being reversed—stops mess, reduces fire hazard.

Send for free catalog.

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ably condensed, has all the earmarks of infanticide. Yet once an article has been condensed, either by the author or by someone else, the result is frequently an improvement. When condensation of articles is approached in the spirit of rendering a service to the reader and for the purpose of promoting more and a greater variety of material in substantially the same number of pages, arguments in favor of it prevail. And for the satisfaction of the author it may be said that length tends to make readers put off reading what, in briefer space, may be of great interest and value to them. Since the objective of writing something is to have it read, authors should welcome whatever leads to that end.

George Stetson, Editorial in *Mechanical Engineering* announcing A.S.M.E. decision to shorten authors' papers.

### Living Freedom's Way

The fundamental, on our side, is the richness—spiritual, intellectual and material—that freedom can produce and the irresistible attraction it then sets up. That is why we do not plan ourselves to shackle freedom to preserve freedom. We intend that our conduct and example shall continue, as in the past, to show all men how good can be the fruits of freedom.

John Foster Dulles  
Evolution of Foreign Policy

### Pursuit of Truth

The history of education shows that the crucial point in the management of universities is not who has the legal control . . . The crucial point in the management of universities is how the legal control is exercised . . . One gets from some of the statesmen of the day the . . . impression, that under the influence of the Cold War they have concluded that a country is not safe unless it is united, which is true, and then that a country cannot be united unless everybody in it agrees with everybody else about everything, which is false . . . That civilization of which a true university is a paradigm is one that is based on the premise that the truth is arrived at by discussion. Discussion implies that there is more than one point of view. The notion that the truth is arrived at by discussion is peculiarly applicable to practical, political, economic matters. A civilization in which the opinion of the majority is taken on such matters and must then be adopted by all is one that is doomed to stagnation. It ignores the fact that the most precious

(Continued on page 29)



# Chlorine...

## for Refrigerants

Ice making, air conditioning and countless other cooling operations depend upon the economy and efficiency of chlorine-made refrigerants.

Uniformly high quality GLC GRAPHITE ANODES play an equally important part in helping the electrolytic industry meet the growing civilian and defense needs for chlorine and caustic soda.

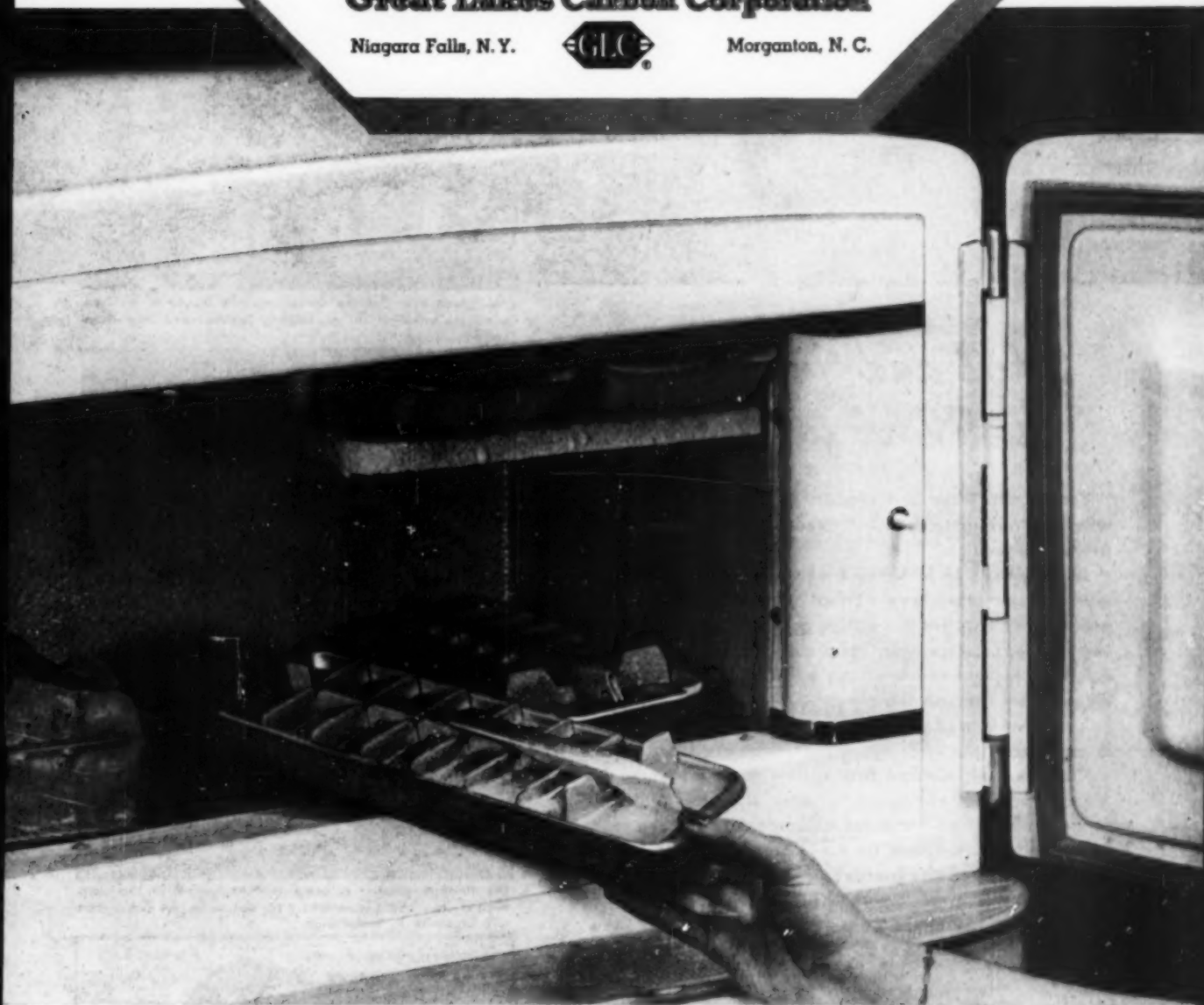
ELECTRODE DIVISION

**Great Lakes Carbon Corporation**

Niagara Falls, N. Y.



Morganton, N. C.

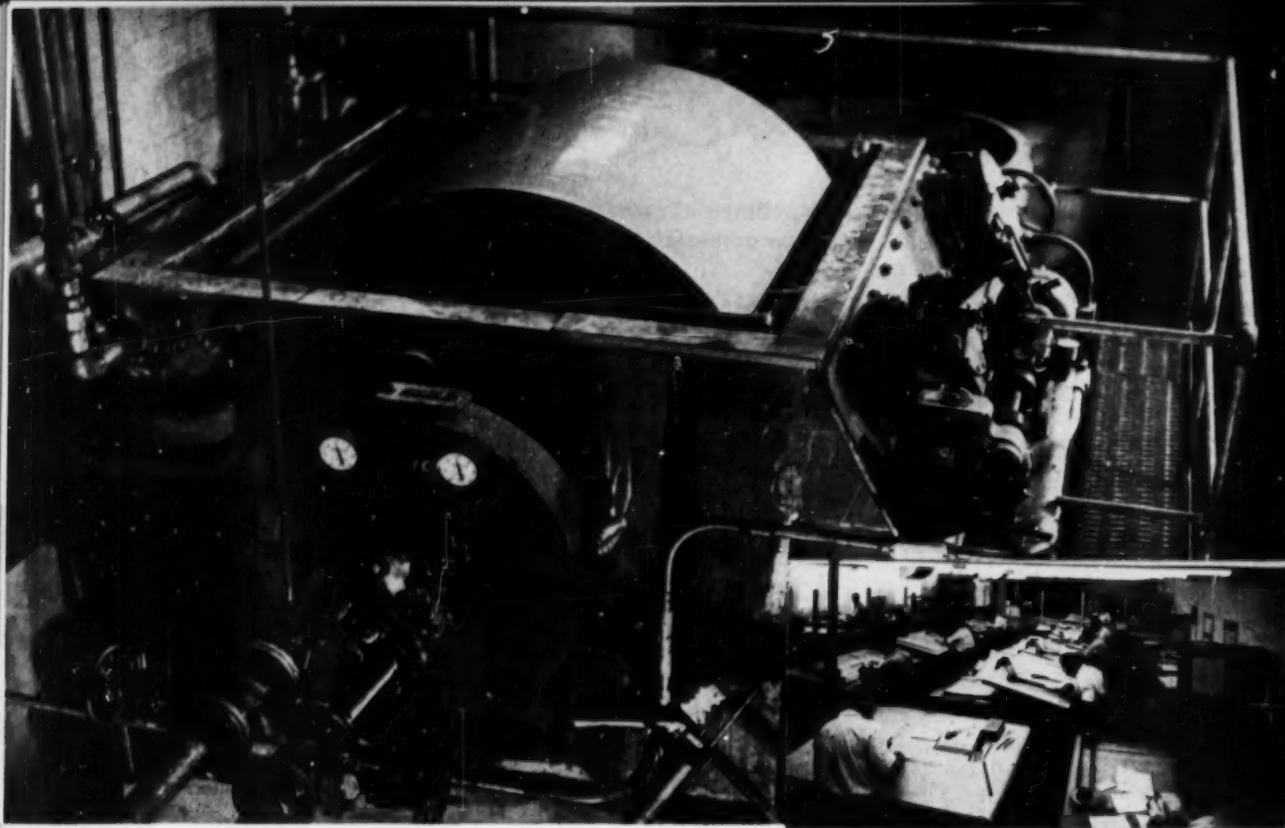


### Graphite Electrodes, Anodes, Molds and Specialties

**Sales office:** Niagara Falls, N. Y.    **Other offices:** New York, N. Y., Oak Park, Ill., Pittsburgh, Pa.

Sales Agents: J. B. Hayes, Birmingham, Ala.; George O'Hara, Long Beach, Cal.; Great Northern Carbon & Chemical Co., Ltd., Montreal, Canada

Overseas Carbon & Coke Company, Inc., Geneva, Switzerland; Great Eastern Carbon & Chemical Co., Inc., Chiyoda-Ku, Tokyo



## *Skill and Ingenuity at Work for You*

Your Eimco filter is a product of skill and ingenuity wrought from more than half a century of service to the process industries.

As a matter of fact, think about it — you wouldn't want it any other way. When you've worked out a process that requires the culture or slurry to be handled *just so* to produce your laboratory results, you can't afford to recommend anything but the finest equipment all the way through the plant.

Your finest product in pressure or vacuum Filtration is an Eimco.

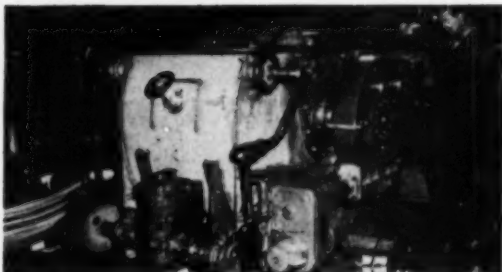
Costs — look beyond first cost — to the savings in higher recovery of values, greater clarity of filtrate, longer trouble free life in the equipment and in the case of the unit shown above, an Eimco precoating unit, about double the life of one precoat.

Write for information on the finest filters available anywhere to The Eimco Corp., P. O. Box 300, Salt Lake City 10, Utah.

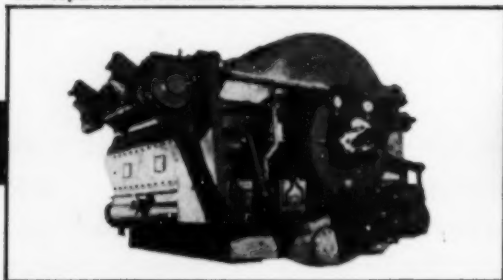
Each Eimco filter for the special process industries receives individual attention in engineering (above) and inspection (below).



Skilled mechanics with a field knowledge of filtration problems machine and assemble your specialized Eimco filter.



The finished product is completely assembled in the shop even if dismantling is necessary for shipment. An Eimco man will supervise its installation.



THE EIMCO CORPORATION

Salt Lake City, Utah, U.S.A.  
Export Office: Eimco Bldg., 37 South St., New York City

*You Can't Beat An Eimco*



possession of any society is the thought of the minority, even a minority of one. The rule of the majority without discussion and criticism is tyranny . . . .

ROBERT M. HUTCHINS  
In "The University of Utopia"

### The Battle Between Creativity and Taxes

Our company put out an issue of debentures to the tune of \$100,000,000—which is not small change in anyone's language. As we took delivery of the proceeds I was reminded of a note Herbert Dow had written to one of his early backers in 1891, in which he acknowledged receipt of a draft for \$75. "I think," wrote Dow, "that will give us enough funds to last for quite a while."

It would be interesting to speculate as to which investment was proportionately the most significant—the \$75 in 1891 or the \$100,000,000 in 1952, which we also hope will "last for quite a while." Very possibly it would be the \$75.

One point, at least, is in distinct contrast. Herbert Dow's prospect of a return on that \$75 was limited only by the effectiveness with which he could put it to work. Today, however effectively we may be able to utilize the \$100,000,000, we are assured in advance that well more than half of the earnings from it will be taken away in taxes. Perhaps this stimulates us to be extra skillful in order that we have anything worth mentioning left after taxes. But what happens when we doubt our ability to realize a worthwhile return—when the reward for creativeness becomes so small that we find it more attractive to be ordinary?

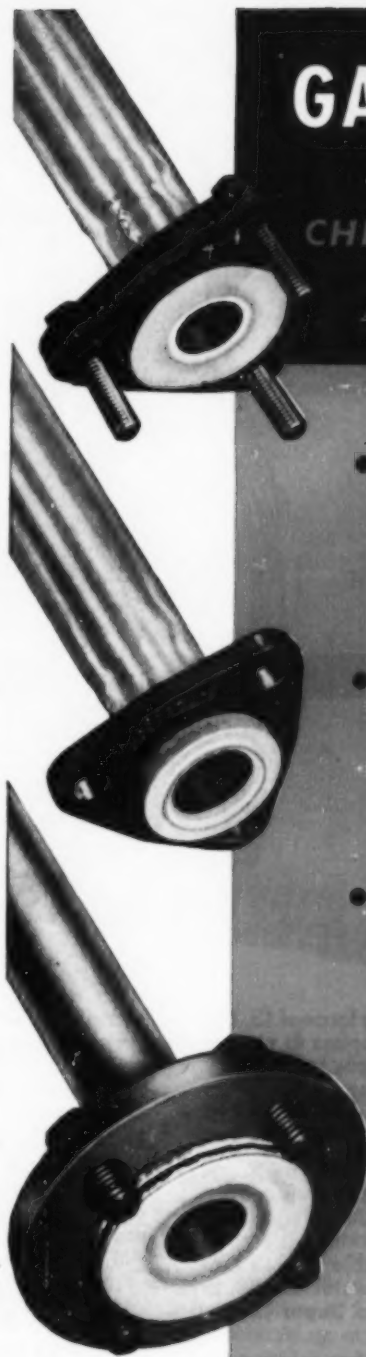
Already we have had the experience of discarding plans for one \$10,000,000 plant, for a product with which we are most familiar, because the potential rate of return after taxes did not justify the competitive gamble.

Leland I. Doan  
The Dow Chemical Co.

### The Editorial "We"

I do not know how the editorial "we" originated, but I think it must first have been employed in an effort to express a corporate or institutional opinion and that in no time at all the individual charged with formulating this opinion forgot all about his basic responsibility and got talking about himself and peddling his personal prejudices, retaining the "we" and thus giving the impression that the stuff was written by a set of identical twins or the members of a tumbling act.

E. B. White  
"The Second Tree from the Corner"  
Harper & Brothers



## GASKETS MADE OF TEFLON

FOR  
CHEMICAL-RESISTANT  
SERVICE

- Chemiseal TEFLON-Jacketed Gaskets with various types of fillers for stainless steel, glass-lined steel and conical-flanged glass pipe. Available for all standard size pipe flanges. Seal at low bolt loads.
- Chemiseal molded TEFLON Snap-on Gaskets match contour of conical-end glass pipe, assure perfect automatic centering of joints and free flow of materials. For all standard pipe sizes from  $\frac{1}{4}$  in. to 6 in.
- Chemiseal TEFLON-Jacketed Adaptors provide a tight, safe seal between conical-end glass pipe, glass-coated steel or similar nozzles of large inside radii and vessels of glass-lined steel, porcelain, Hareg, etc. Easy to handle, single units, combining a steel bearing ring for rigidity and a resilient core for perfect seal, contained in a chemically inert TEFLON Jacket.

Ask for Bulletin TG-953.

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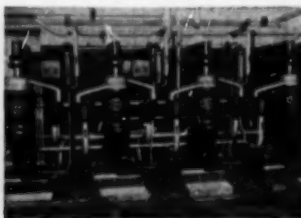
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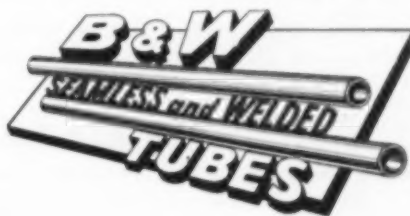
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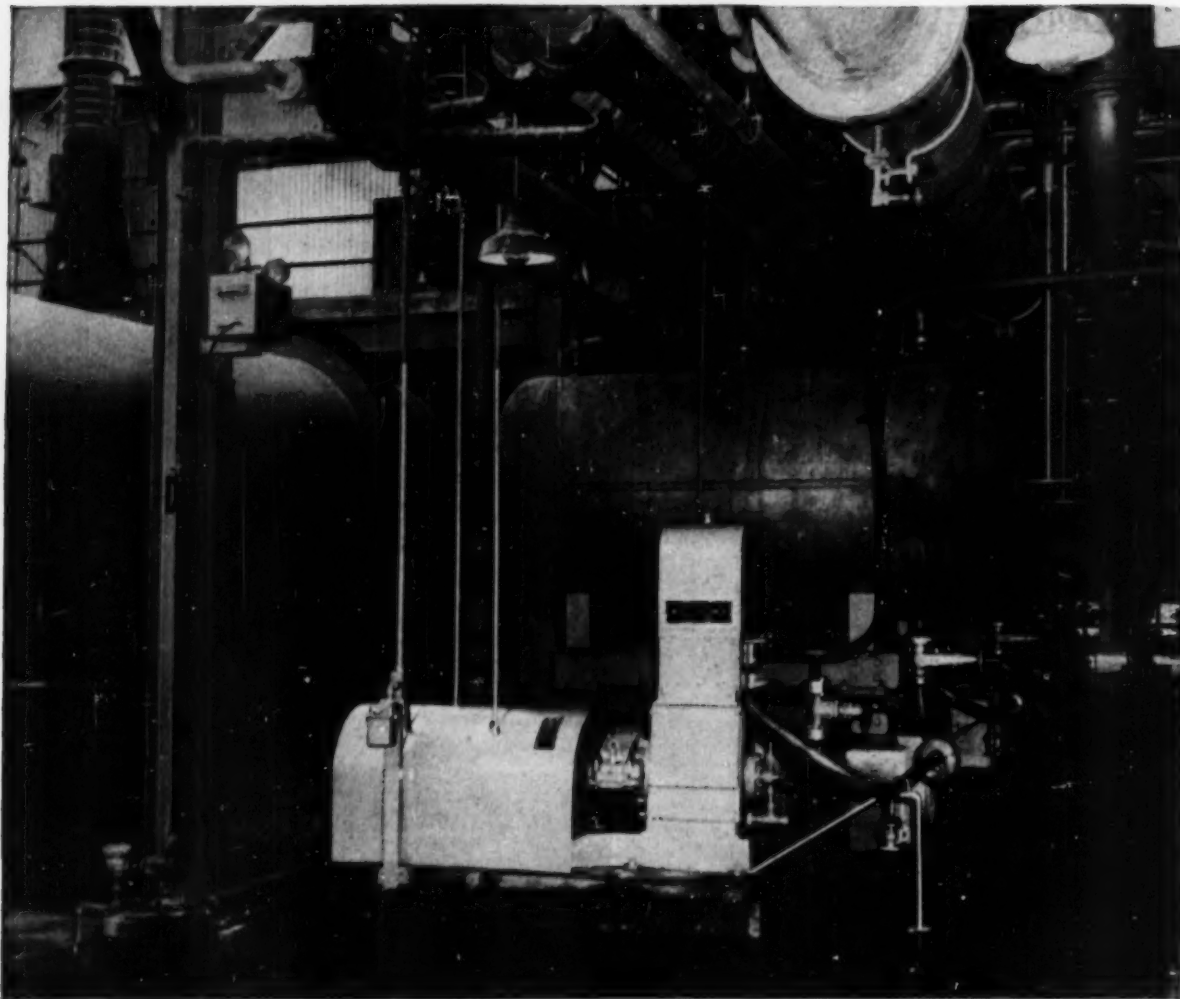
at high temperatures, there will be a difference in corrosion resistance. The 18-8 grade may lose its corrosion resistant properties while the other three grades maintain theirs. This is because of slight differences in chemistry—5 parts in 10,000 in carbon content or the addition of 5 to 7 parts in 1,000 of columbium or titanium. Thus, your particular end use service condition, in addition to the basic cost of materials, should dictate which grade to use.

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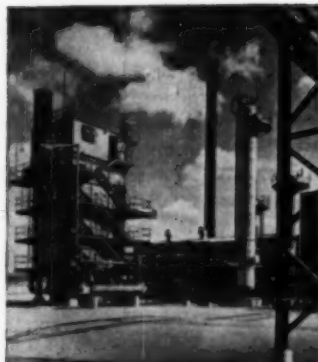
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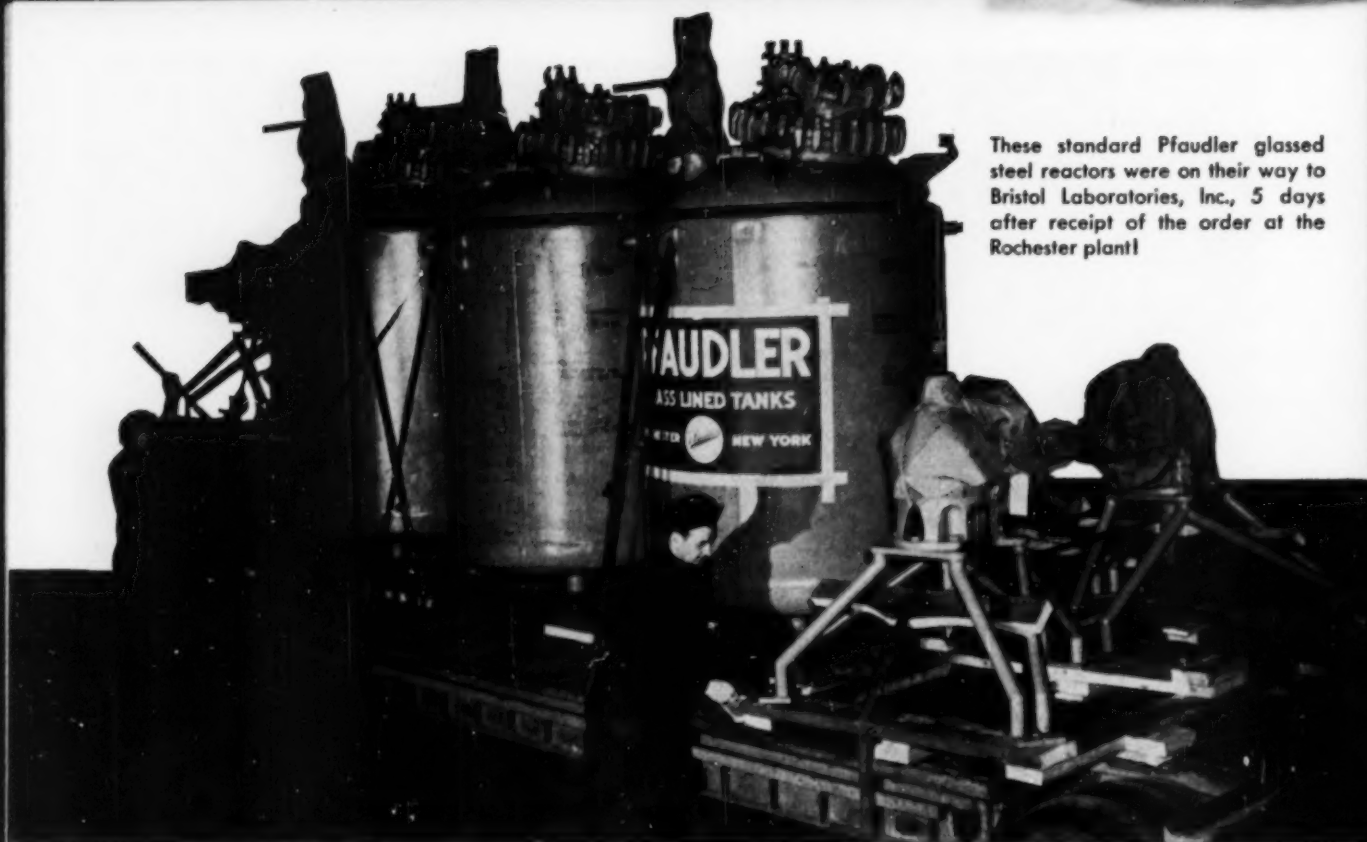
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# Opinion and comment

## TEAM WORK IN THE TRAINING OF YOUNG MEN

An industrial concern that is trying to perpetuate itself must have some systematic and effective method for solidly incorporating young men into its structure. Too often the methods employed are haphazard and spasmodic, or, if not, they overemphasize the physical aspects of the business and fail to recognize the vital importance of the relationships involved.

It may seem unnecessary to state the reasons for introducing young men into an organization, but some of them apparently are frequently lost or forgotten. The most frequent reason given is for the replacement of those who have dropped out because of death, retirement, or other cause of separation from the company. Next to that comes provision for an expanding business with its corresponding need for more people. However an equally important reason is to maintain a proper balance in the age groups so that the average level corresponds to one of vigorous and creative energy supported by balanced judgment.

Young men have the favorable characteristics of being energetic, optimistic, enthusiastic, ambitious, flexible in their ideas, and last, more durable than older men. On the other hand they are likely to exhibit the unfavorable characteristics of being unseasoned, undeveloped in their judgment, rash, inexperienced, undiplomatic, shortsighted, and weak in team spirit.

The real problem in training, then, is to utilize the favorable characteristics without suffering undue disadvantage from the unfavorable ones while these are being diminished or eliminated by a process of education and increasing maturity.

Most training programs have given reasonably adequate attention to the process of familiarizing the trainee with those physical aspects of the business which it is necessary for him to know. However an adequate program brings into focus, people and their methods of doing things in a manner which is beneficial both to the teacher and the student.

The great difficulty experienced by people in an organization, and perhaps people more or less universally, is to separate emotional approaches from reasonable approaches, or at least to use emotional language sparingly and only where experience teaches that it will support the main objective.

It must not be supposed that every seasoned executive has reached that point of balance where he relies almost exclusively upon the reasonable approach. That there are still a large number of 'give 'em hell' executives carrying on in the same old way as their predecessors is well known. Hence, we can hardly expect that any clear-cut rules of personal interchange within the organization can be applied without some confusion to the novice except in the most fortunate companies. Nevertheless, the techniques are present in every successful organization, and can be observed and understood by the beginner with the proper guidance.

Many people seem to believe that team spirit is something that is generated by emotional interchange and arm waving. They forget or do not know that a

team is created by two factors: first, every individual must believe that he is contributing an essential part to the team objective; and, second, every individual must be thoroughly convinced that the unified team effort is far more effective than any independent effort of his own. The emotional touch is only the final bit of inspiration to the trained team which permits it to put outstanding effort into a part which it already knows how to play smoothly and well.

It is a grave mistake to make an individual feel that he is unessential, or to try to substitute emotional unity for unity based on coordinated effort.

A training program which incorporates these principles benefits not only the individual but also the entire organization. It is impossible to teach something that you do not know and understand yourself, and there are very few who could not profit by a more consistent application of the reasonable approach and the development of team unity.

R. P. DINSMORE

## THE GULF'S PROGRESS

Once again the Texas-Louisiana gulf coast region forges ahead as a vigorously growing area of chemical manufacture. This news is welcome, as not much has been heard lately from this region. We have been impressed by the Frankfort, Kentucky, development. More recently Tuscola, Illinois, has literally typhooned into top place with its promise of bounteous alcohol, etc. Throughout all of this the traditional magnetism of the Far North has kept Canada in our minds as a chemicals producing region of great promise.

Now we are greatly relieved to learn that the Southwest is once again on the move—chemically. Word has been received that the Gulf Oil Corporation is starting on the world's largest ethylene facility—destined to increase the total U. S. production by 10 per cent!

Ethylene is not, of course, an end-product. Every pound of this additional 3,000,000,000 cubic feet a year rated capacity will go into the manufacture of other products—polyethylene, ethylene oxide, polyglycols, styrene, ethyl chloride, and so on. Doubtless this much added capacity will call for several other new plants, which will require new equipment and will mean new jobs for chemical engineers.

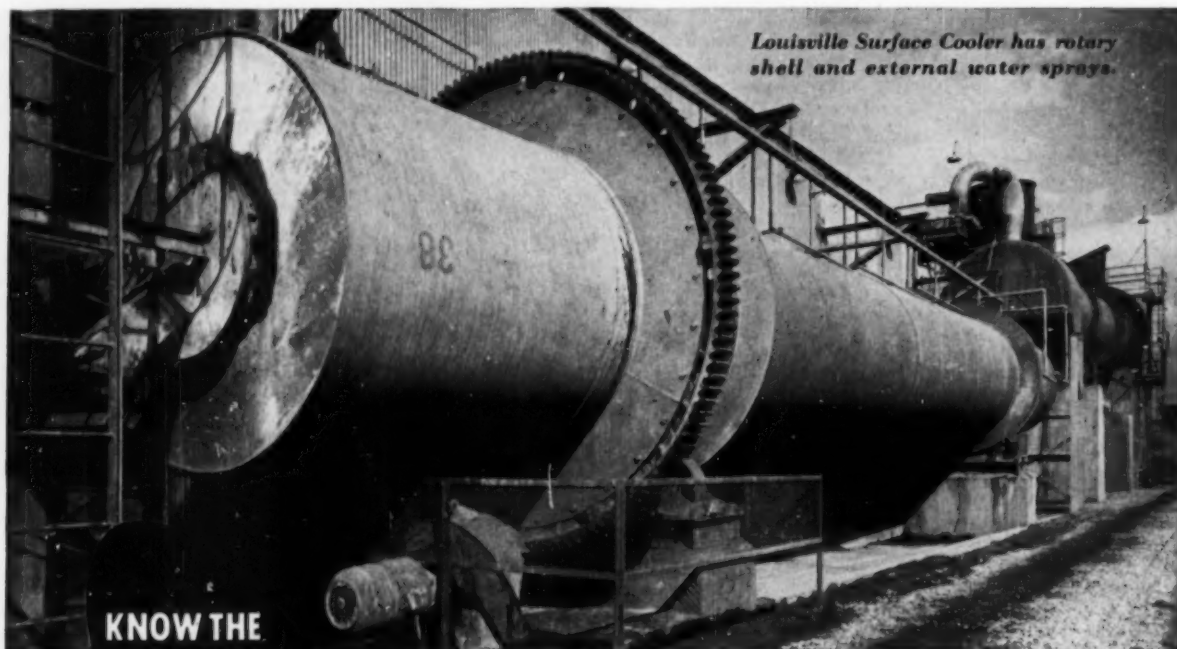
An existing pipeline (over 130 miles long), already used to transport ethylene in the region between Orange and Texas City, will carry the increased volume. Plants using the ethylene we presume will be located within its service range.

This venture of Gulf's is especially significant in these days of talk about impending business recession. It reveals a firm belief on the part of a major corporation in the stability of future markets. Furthermore it emphasizes the continual growth of the petrochemical segment of the chemical industry.

Chemical Engineering Progress salutes this new venture as another advance in the chemical process industries.  
J. M.



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# Recovery of Phenolics

## from waste effluents

Radcliffe G. Edmonds and George F. Jenkins

Carbide and Carbon Chemicals Company, South Charleston, West Virginia

**A**n unusual and unprecedented investigation is currently in progress on the Ohio River and its tributaries for the explicit purpose of increasing the understanding of the behavior of phenolic wastes when discharged into receiving bodies of water. In a cooperative effort being conducted by seven major steel companies under the guidance of the Steel Industry Action Committee, a far-reaching study is being made to determine as accurately as possible what the die-away rate of phenolics in these streams really is.

Such intense interest in the problem of disposal of phenolic wastes in this region, however, is not of recent origin. Rather this is just another in a long history of improvements and developments toward the objective of abatement of this source of pollution of the many public water supply systems dependent upon the Ohio River and its tributaries. Progress is tangibly attested to by available publications on the subject (1).

The vast scope of the present survey may be appreciated when it is realized that it will be conducted on the stretch of the Monongahela River between Fairmont and Pittsburgh and on the Ohio River between Pittsburgh and

Wheeling. Seven steel companies are planning to run repeated traverses across both these streams above and below their plants. When the data are compiled, they will be correlated and examined to determine the rise and fall of concentration of all phenolics discharged to these streams.

In addition, as part of the work being done under the American Iron and Steel Institute Fellowship at Mellon Institute, directed by R. D. Hoak, the origin of taste- and odor-producing substances from natural sources is being thoroughly investigated. It has already been disclosed that phenolic substances are produced not only by industrial activity but also by the mere presence of human beings and both wild and domestic animals, and large quantities are produced by the natural decay of vegetable matter.

With such a background of interest regarding the undesirability of discharging pollution of any kind to the Kanawha River, a tributary of the Ohio, and particularly regarding discharge of taste- and odor-producing substances, the need for control and abatement facilities was recognized early in the process-design phase of Carbide's coal-hydrogenation installation planned for the plant at

Institute, W. Va. (2). Early in 1950 the first preliminary plans were drafted. During the subsequent two years intensive engineering and laboratory work was concentrated on this aspect as well as on the over-all design. The waste-disposal facilities and the phenol-extraction system were given equal attention and priority with even the most difficult and unusual portions of the basic hydrogenation operation. Thus, when full-scale operations began early in 1952, the equipment for water-pollution abatement also was ready to function and, following a short period attended by the usual start-up problems and difficulties, soon reached a normal and uniform degree of efficient operation.

During the first year of operation nominal attention was devoted to the pollution-abatement equipment in view of the fact that full operating and engineering interest was required to achieve desirable operation of the main plant. In January of 1953 however performance of the phenol-extraction equipment came under intense scrutiny, and extensive investigation and test work was performed on that apparatus during a greater part of the year. The interesting data which evolved substantiate that



R. G. Edmonds is associated with Mathieson Chemical Corp. as project director in the engineering and development division. Mr. Edmonds was graduated from Massachusetts Institute of Technology with B.S. and M.S. degrees in chemical engineering. With Carbide and Carbon Chemicals Co., his activities have included nine years in design engineering, assorted engineering research work on the Manhattan Project, and eight years of engineering and development concerned with raw-material utilization. This work has led to the installation of Carbide's coal-hydrogenation pilot plant. For this project he was in charge of process design.



With Carbide and Carbon Chemicals Co. since 1933, George F. Jenkins is now a project leader in the engineering department. He received his professional degree of chemical engineering at Columbia University in 1932. While in Texas during the initial installation and start-up of the Carbide plant there in 1941 and 1942, he participated in ESMWT program with Texas A. & M. college in teaching chemical engineering.

In 1944 he was assigned to the Manhattan District in New York and New Jersey and is still consultant for several projects at Oak Ridge, Tenn. Since 1948 he has devoted considerable time to air- and water-pollution abatement problems.



the design and performance of this equipment meet expectations. As must be expected, unknowns have also appeared, some of which have been solved and others still await solution. However, this study will be continued, and it is not improbable that complete understanding of the materials involved and methods of coping with them will be achieved.

Not the least of the problems encountered in evaluation of the performance of the phenolic-extraction system, was the determination of the material balances by analysis of the various component streams. The Gibbs test (3) has long been the criterion in such determinations. For certain phenolics, that method has a sensitivity of about 25 parts/billion for a skilled technician. Disadvantages are (a) two days required for each determination, (b) failure to detect all phenolic compounds, (c) a modified procedure necessary to detect concentrations below 25 parts/billion. The recently developed method described as the distilled 4-aminoantipyrine method is much more rapid but lacks sensitivity below 100 parts/billion unless a modified procedure is employed to concentrate lower values above that limit. A sensitized technique of the D.A.A.P. method, presently under field testing by the many industries involved as well as by the U. S. Public Health Service, gives promise of improvement in speed and accuracy. In the present case, dealing for the greater part with higher concentrations, a rapid spectrophotometric method for determination of total phenols in the various streams was employed. This method is a slight modification of that described by M. J. Murray (4). As will be shown later, even the revised procedure has certain limitations which if recognized at the outset will yield sufficiently accurate and reproducible results.

Among the many factors taken into consideration in the design of the extraction system were the two primary features—(a) the economic or monetary value of the materials recovered compared with the costs of recovery and (b) the actual effect of the initial and final materials on the taste and odor thresholds of public water supplies downstream from the Institute plant. The costs of operation are just about offset by the value of the materials recovered.

The polluting effect of these materials could be a serious problem inasmuch as the Nitro plant of the West Virginia Water Service Company is located barely 2 miles downstream from the Carbide plant at Institute, and, more important, intake to this public water supply system is on the same side of

the Kanawha River as the Carbide plant site. Consequently, it is mandatory not only to achieve maximum control of the pollutants, but also to have constant assurance and record of such control. All the effluents from the coal-hydrogenation plant are therefore continuously policed by automatic sewer samplers, and daily analyses are performed on composite samples collected by these continuous units. The operators of the Nitro Treatment Plant, which supplies water to the city of Nitro, part of the city of South Charleston, and certain intervening areas, including the plant in the Institute area, had looked forward to very serious treatment problems with the advent of unprecedented low flows in the Kanawha River during the autumn of 1953. The fact that the anticipated serious problems failed to materialize, is proof that the pollution-abatement methods described herein have been successful.

#### The Process

Although the majority of the process-water contaminants from the coal-hydrogenation plant located at Institute, West Virginia, appear to be similar to those found in the aqueous liquors from coke plants producing by-product coal chemicals, there are many inherent features of the hydrogenation plant which tend to make the recovery problem unique. In the coal-hydrogenation process, dried, pulverized coal is partially dissolved in recycled process oil to form a fluid mixture which is pumped into the high-pressure reaction system. Thereafter the process materials are handled as fluids throughout the reaction and separation equipment. Consequently, it is possible to withdraw the desired gas, oil, water, and residual-solids streams at appropriate points in the separation process. The oil streams constitute the major liquid products from the plant—chemical raw materials. The gas streams provide fuel and are a source of by-product hydrocarbon gases for aliphatic chemical synthesis. The solids and water streams, which are waste products of the process, must be removed and disposed of by appropriate methods. The concentrated solids are cooled and then handled in a manner similar to fly-ash disposal from power plants. The recovery of process material from the water effluent before it is discarded to the sewer is the subject of this paper.

A large fraction of the oxygen contained in the coal fed to the process is converted to water, since the hydrogenation conditions favor this reaction. Actually, this water quantity may approach 8% of the ash and moisture-free

coal weight. To this chemical by-product is added a small stream of process water introduced as direct steam for heating or through flushing connections. However, every effort is made to restrict the total quantity to a minimum value. By this means it becomes easier to maintain the net daily discharge of water-soluble process material within acceptable limits without the necessity of reducing its concentration to an unusually low value. Thus part of the waste-disposal problem has been solved by first removing process material from a small stream, which is finally diluted ten-thousandfold or more with uncontaminated plant-cooling water.

A complete analysis of the contaminants in the water stream is not known, but the presence of several classes of water-soluble organic materials has been disclosed. Since the water is constantly recycled to the high-pressure reaction system to prevent deposition of inorganic salts from the organic product, it is to be expected that some build-up of these water-soluble, inorganic materials will also be obtained. In addition, the water contains dissolved gases, such as ammonia, hydrogen sulfide, carbon dioxide, hydrogen, and hydrocarbons. The recovery system is designed to extract from the water layer any emulsified immiscible oils, the soluble nitrogen bases, and the dissolved oxygenated compounds, such as phenol.

#### Description of the Recovery System

The method selected to recover this organic material from the process-water stream is shown schematically in Figure 1, the process flow diagram. The process streams containing water are separated from oil in a decanter operating at 30 lb./sq.in. gauge. The water layer is then accumulated in a raw-water feed tank at 60 lb./sq.in. gauge, from which it is fed through a preheater to a packed degassing column. Here the process water is stripped under pressure at 150° C. with direct steam to remove dissolved gases, including ammonia, hydrogen sulfide, and carbon dioxide. From the base of this column, the water is heat-exchanged with the feed, cooled to atmospheric temperature, and then stored in a cycle water tank. A portion of this stored water, corresponding to the net accumulation of water in the process system, is fed continuously to a packed extraction column, where it is scrubbed at atmospheric temperature and pressure with an appropriate organic solvent. Isopropyl ether has been selected as the most advantageous solvent for use in the coal-hydrogenation plant. The water raffinate, from which most of the organic material has been removed, is then stripped with direct steam in a small packed column. This removes the dissolved solvent from the water before it flows to the holding and dilution system. The stripped water is used to pre-



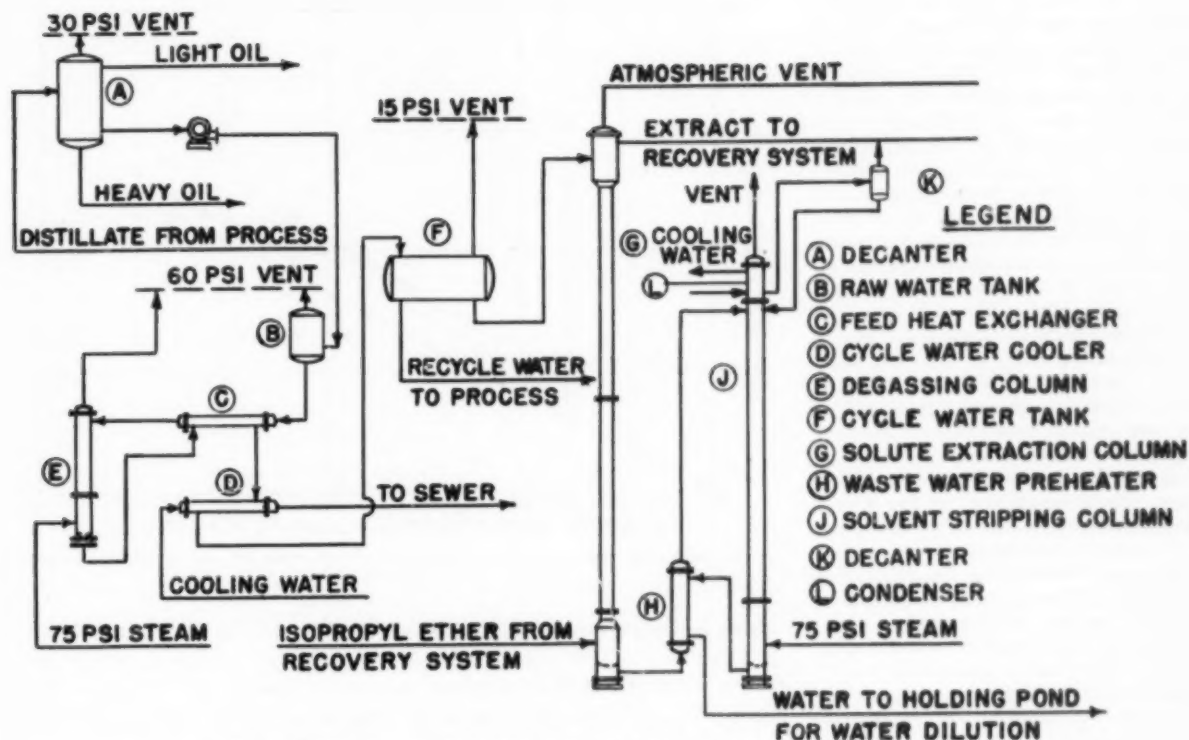


Fig. 1. Waste water extraction system—process flow diagram coal-hydrogenation pilot plant.

heat the raffinate fed to this column. The ether extract containing the dissolved phenolic material is processed in another section of the plant. There the ether is recovered relatively free of contaminants and suitable for recycling to the extraction column, and the extracted phenolic material is combined with the plant oil streams. A brief summary of the equipment used is shown in Table 1, and typical material flows during recent operations are contained in Table 2.

#### Analytical Methods

The literature (1) describes a number of methods suitable for analysis of phenol in aqueous solution. Some of these are capable of directly determining phenol in dilutions as low as 3 parts/billion. However, preliminary attempts to analyze either the various aqueous streams within the coal-hydrogenation process or the effluents have yielded discordant results. An effort has therefore been made to develop a method of analysis which will give reasonably reliable results for the comparatively large number of phenolic homologues present and which will not prove erroneous in the presence of hydrocarbons, nitrogen compounds, isopropyl ether, or other materials found in the sample streams. Such an analysis has been developed, although its present limit of sensitivity is no greater than 0.5 part/million of phenolic material in water. Most striking is the indication

Table 1.—Summary of Equipment Specifications

ITEM	DESCRIPTION
Decanter	8-ft. O.D. by 12-ft.-long, horizontal steel tank for 30 lb./sq.in. pressure
Raw water feed tank	4-ft. O.D. by 6-ft.-6-in.-high, vertical stainless steel tank for 85 lb./sq.in. pressure
Feed heat exchanger	93 sq.-ft. stainless steel tubular heat exchanger for 75 lb./sq.in. pressure
Cycle water cooler	101-sq.-ft. chrome steel tubular heat exchanger for 75 lb./sq.in. pressure
Degassing column	16-in. O.D. by 17-ft.-4-in.-high, stainless steel column for 75 lb./sq.in. pressure; packed with 1 1/4 in. Raschig rings
Cycle water tank	4-ft.-6-in. O.D. by 8-ft.-long, horizontal steel tank for 30 lb./sq.in. pressure
Solute extraction column	12-in. O.D. by 50-ft.-high steel column for 75 lb./sq.in. pressure packed with 3/4-in. Raschig rings
Waste water preheater	4-sq.-ft. steel helical coil heat exchanger for 50 lb./sq.in. pressure
Solvent stripping column	12-in. O.D. by 28-ft.-high, steel column for 75 lb./sq.in. pressure; packed with 1-in. Raschig rings

Table 2.—Waste-Water Extraction System—Material Flow Summary

STREAM	FLOW RATE	PHENOL CONTENT,* %
	gal/hr.	
Raw water feed to degassing column	360	Not measured
Cycle water feed to extraction column	120	1.25
Isopropyl ether solvent to extraction column	105	0.0045
Isopropyl ether extract from extraction column	103	1.78
Water raffinate from extraction column	122	0.095

\* Calculated as m-cresol from base-line technique of recording 290 mμ ultraviolet absorption measurements of aqueous sodium hydroxide solutions.

of 0.07 to 0.10% phenolics in the water raffinate by this new method; whereas the D.A.A.P. or the Gibbs method shows the presence of only 0.0006 to 0.0013%. The procedure was adapted from one reported by Murray (2), which is based on an ultraviolet absorption method using a sodium hydroxide solution of the phenolic material at the spectral position of 290 m $\mu$ . A baseline technique with a Cary spectrometer is used to obtain a continuous record of the ultraviolet absorbance in a 10-mm. silica cell. The calibration curve is shown in Figure 2, covering the recommended range of 0.5 to 1.5 scale units of the spectrometer. Figure 2 indicates the calibration difference between the revised method and that of Murray, who used the total absorbance. For preliminary evaluation, *meta*-cresol has been selected as typical of the water-soluble phenolic material. Further work with plant-derived material may necessitate a small change in the calibration constant, but preliminary indications do not substantiate this possibility.

The more concentrated aqueous samples are analyzed by dilution with 0.4% aqueous sodium hydroxide to the proper strength for measurement in the absorbance range of 0.5 to 1.5 scale units. The isopropyl ether samples are extracted with equal or larger volumes of this aqueous sodium hydroxide solution for analysis in a similar manner. The presence of small amounts of dissolved isopropyl ether does not affect the results.

#### Results of the Raffinate Analyses

Experience shows that the ultraviolet absorption method yields reproducible analytical results, indicating an unextracted phenolic residue in the water raffinate roughly a hundred times the values obtained by standard methods. These differing values emphasize two important properties of this residual material fully confirmed by subsequent experiments. It has very slight volatility at 100° C., and the distribution coefficient between water and isopropyl ether is exceedingly unfavorable. Furthermore, it has been found that one volume of an anionic exchange resin, Amberlite IRA 400, selectively removes more than 99% of the material from twenty volumes of raffinate and that the resin may be regenerated with aqueous sodium hydroxide. Evaporation of the raffinate to dryness, followed by carbonization, destroys the phenolic material completely.

A preliminary experiment of particular interest has indicated that this unextracted phenolic residue behaves quite differently from phenol in tests for odor threshold after chlorination. Whereas chlorinated phenol can be de-

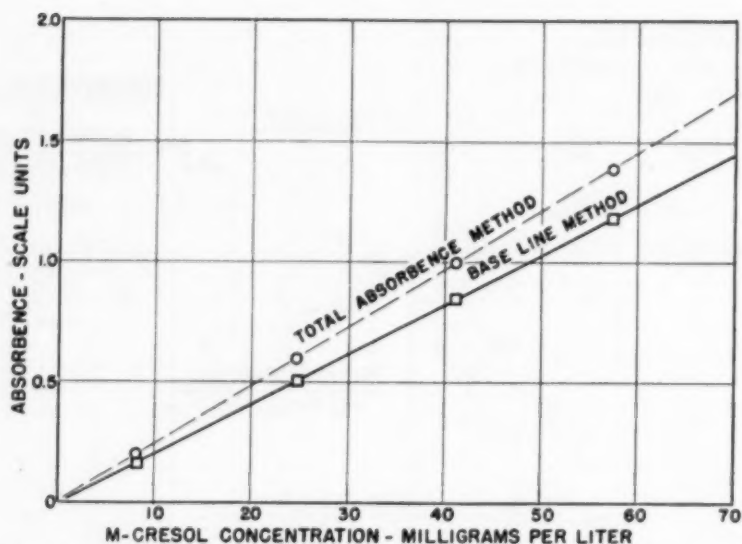


Fig. 2. Calibration curves of sodium *m*-cresolate solution using 290 m $\mu$  ultraviolet absorption analysis.

Table 3.—Comparison of Analytical Results for Phenolics \* in the Water Raffinate

	%
Phenolics content of recycled isopropyl ether .....	0.0045
Calculated phenol content of water raffinate in equilibrium with recycled isopropyl ether .....	0.00046
Phenolics content of water raffinate, by Gibbs method .....	0.0009
Phenolics content of water raffinate, by ultraviolet absorption method .....	0.095
Phenolics content of water raffinate after acidification and extraction three times with equal volumes of isopropyl ether by ultraviolet absorption method .....	0.082
Phenolics content of water raffinate after acidification and extraction three times with equal volumes of dibutyl carbitol by ultraviolet absorption method .....	0.078
Phenolics content of distillate from acidified water raffinate, leaving 5% residue in kettle by ultraviolet absorption method .....	0.002
Phenolics content of effluent from Amberlite IRA 400 ion exchange resin treatment of water raffinate by ultraviolet absorption method .....	0.0003

\* Phenolics calculated as cresol.

tected at dilutions as low as four parts per billion, chlorination of the raffinate indicates that the odor threshold lies in a considerably higher concentration range, approximately 870 parts/billion. In this case the normal dilution of the raffinate by cooling water would be wholly adequate to permit direct disposal. Furthermore, it is likely that the odor threshold found for the raffinates tested is a measure principally of the residual extractable phenols. Their presence may be shown by the analytical results of the Gibbs method. This preliminary information thus casts reasonable doubt on the necessity of removing this extremely water soluble substance in spite of its apparent phenolic character. Nevertheless, experiments are continuing to identify the class of compound responsible and to formulate a practicable method of removal from the water effluent. Present conjectures indicate the existence of a similarity with

the behavior of pyrocatechol or related polyhydric phenols. A summary of experimental results and analytical evidence is shown in Table 3.

#### Discussion of the Phenolics Recovery Process

The raw cycle water decanted from the process streams contains dissolved gases and other impurities, which would probably interfere with continuous operation of the extraction system. For this and other reasons related to operation, the precaution of removing all components which can be readily stripped at 60 lb./sq. in. gauge and 150° C. is taken in order to improve the subsequent recovery step. In this manner essentially all of the dissolved and reacted by-product gases are stripped from the stream and are made available for recovery from the effluent vapors. With the present scale of operation, it is more convenient to dispose of the

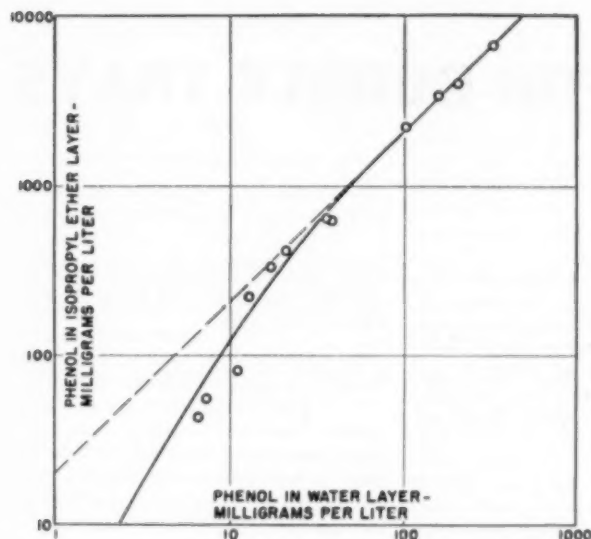


Fig. 3. Equilibrium distribution of phenol.

relatively small quantities of these materials by adding them to fuel gas, since they are removed at a pressure of 60 lb./sq.in.gauge.

It is important to note that air and dissolved oxygen are excluded from this system because the process streams are produced under drastic hydrogenation conditions and the recovery equipment is connected to inert-gas-atmosphere vent headers. This not only greatly reduces the possibility of corrosion but also simplifies the use of a solvent, such as isopropyl ether, which is sensitive to peroxide formation. The recovery process is thus operated with the same precautions observed in the separation of the coal-hydrogenation-plant oil streams.

The choice of isopropyl ether as a suitable solvent is dictated by two considerations—low cost and favorable distribution coefficient. Figure 3 shows laboratory data indicating the distribution of pure phenol between water and isopropyl ether phases. This determination was made as a rough check in guiding the choice of solvents. It is obvious that the distribution coefficient is satisfactory, although there are indications that the solvent becomes less effective in the extraction of dilute aqueous solutions. As plant operation becomes less experimental, the effectiveness of this and other solvents should be compared in relation to the complex mixture actually extracted from the water layer, rather than by use of the semiquantitative indication provided by the phenol equilibrium. Although esters, other ethers, and similar oxygenated solvents may be employed, isopropyl ether has been selected, since it is readily available in this plant as a low-cost solvent with suitable physical and chemical properties. With different

scales of operation, consideration should again be given to various aromatic compounds, such as alkyl benzenes and chlorobenzenes, which may well have more desirable solvent properties. In any case, the final selection of a solvent will be influenced by the composition of the recovered phenolic solute, since the incomplete recovery now attained is ample evidence that oxygenated solvents capable of nearly complete phenol extraction are inadequate for removal of other materials present in the water phase.

Although the ether extract is conveniently separated in this coal-hydrogenation plant by stripping ether from the recovered material to obtain fresh solvent for the water-extraction step, consideration has been given to alternate means of recovery. It is obvious that the dilute ether solution obtained in this extraction will require an appreciable amount of heat for separation by distillation. Since the streams are relatively small, this is not considered prohibitive, and a relatively large excess of solvent is normally employed. It is also possible to reextract the phenolic material with aqueous caustic solution, as is done in analysis of the ether streams, in order thus to concentrate this fraction of the recovered material. However, because of the variety of organic material extracted from the water and because combining this recovered material with the main process streams is preferred, the distillation method has been chosen as being more direct for the present scale of operation. It is recognized, however, that further knowledge of the product composition may alter this choice. In any case, the selection of the best method of recovery from this solvent extract will constitute a separate problem for each installation.

#### Significance of Results

1. A continuous countercurrent extraction process appears to be well suited for the recovery of process material from the water effluent of a coal-hydrogenation plant as long as the volume of water treated is held to a minimum.
2. Isopropyl ether appears to be as effective and economical a solvent as any investigated for the extraction of the water effluent from the process.
3. A modified ultraviolet absorption method, using a base-line technique at 290 mμ, has proved reproducible and convenient for phenolic contents above 0.0001%. Comparison with standard methods of phenol analysis has disclosed the presence of a class of phenolic compounds not previously indicated. This material is much less volatile and far more soluble in water than phenol or the cresols.
4. Preliminary tests have indicated that the unextracted phenolic residue in the water effluent differs significantly in physical and chemical properties from phenol, and so there is a need to establish tolerance limits to govern the degree of recovery required for this different class of contaminant.
5. In order to proceed intelligently to modify the present extraction process, it is necessary to identify the classes of compounds involved and to develop an alternate process capable of completely removing all such material.

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# A DESIGN METHOD FOR BUBBLE TRAYS

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A sequence of steps for the design of bubble trays leads to the over-all dimensions of the tray; its relation to the trays above and below; the selection of the number, size, and style of bubble caps and downcomers; and the rating of the tray layout relative to its ultimate capacity. The various equations or numerical rules used in the step design relate to the laws of motion assumed to govern the flow of vapor and liquid as the two phases reach first a zone of generally uniform and intimate mixing and thereafter zones in which the phases separate one from the other.

Bubble caps are, of course, only one of many devices suitable for directing the flow of vapor and introducing it below the liquid. Caps have been used in many shapes, sizes, and arrangements, some good, others perhaps not so good. The extent of their popularity in the past is illustrated by their use where some other device might have been more efficient or more economical. One obvious reason is the acceptance of bubble caps in the distillation industries; a more fundamental reason is the suitability of caps at low as well as at high vapor rates because of the use of a generous part of the available head for controlling the flow of the two phases and forcing their paths to cross in the zone of contact. Because a part of the head controls the flow, an equivalent part of the total volume or cross section of the tower is no longer available as a mixing or contacting zone. Part of the total volume is needed instead for bringing the dispersed liquid of the contacting zone into a denser phase in the downpipe so that the total head can be exerted once more to accomplish the two functions of distributing and contacting.

The design is based on the concept of a division of the cross section of the tower into zones: a zone for contacting and above it a zone for the elimination of entrainment, an outlet zone for liquid collection and a corresponding zone for the inflow of liquid from the tray above. Each of these zones is considered to be more or less heavily loaded according to the relation between the areas required to handle the design rates (as established by a criterion of good practice) and the corresponding areas installed in any particular tray

layout. Furthermore the interaction between vapor and liquid, the range in which potential capacity can be used for either incremental vapor or liquid loading, and pressure drop, which is influenced by tray layout and relative vapor and liquid loading, must be considered.

## Entrainment

The kinetic forces acting on a suspended liquid droplet of a particular critical diameter yield the familiar equation for allowable superficial linear velocity:

$$u_a = \frac{q}{a} = K_1 \sqrt{(\rho_L - \rho_V) / \rho_V} \quad (1)$$

The corresponding equation for mass velocity is

$$G_a = \frac{w}{a} = K_2 \sqrt{(\rho_L - \rho_V) \rho_V} \quad (1a)$$

It is usually more convenient to express the linear velocity in ft./sec. and the mass velocity in lb./hr.(sq.ft.), on which basis  $K_1$  and  $K_2$  would differ by a factor of 3600.

In the literature the area generally used is the entire cross section of the tower; but this is not entirely logical, as the entrainment which occurs in the zone above the active caps is not directly influenced by the presence of other zones such as the inlet and outlet downcomers. A better practice is to exclude downcomer areas and also losses at the tray periphery (11). In order to represent the local velocities above the region of the caps, the areas occupied by the inlet and outlet downcomers should be excluded, likewise gaps caused by the omission of caps along the edges of the cap region. Thus a general cap area and above it an equal vapor disengaging area are left. The required cap area or disengaging area, found through use of Equation (1), is designated by the symbol  $a$ ; likewise, the installed cap area (the region in a specific tray layout given over to caps) is called  $A$ . The ratio  $a/A$  then becomes a measure of the relative vapor loading and of the entraining tendency.

The required cap area, sq.ft., is then

$$a = \frac{w}{K_2 \sqrt{(\rho_L - \rho_V) \rho_V}} \quad (1b)$$

which may be expressed in terms of operating conditions and physical properties in the form

$$a = \frac{w}{f_a \sqrt{\frac{MP(s_L - s_V)}{TZ}}} \quad (1c)$$

Numerical values for the constants are taken in accordance with Table 1, with  $K_1$ ,  $K_2$  and  $f_a$  a function of the tray spacing ( $H''$ , in).

The vapor loading is then expressed as a ratio of the required to the installed cap area. Ratios of  $a/A$  in excess of 1 produce a rapid increase in entrainment, with about 1.3 being an ultimate upper limit. Even at lower vapor loadings the degree of entrainment might be objectionable, especially if only a little reflux were to be used. Intermediate between both the extremes, the case in which  $a/A = 1$  represents a vigorous tray action with good contacting as between vapor and liquid, accompanied by a moderate degree of entrainment. Furthermore, this case becomes equal to the design vapor rates (20 to 40% conservative) as found by Souders and Brown (9), provided that the installed cap area occupies 60% of the tower cross section, thus leaving, say 16%, for edge losses and 12% each for inlet and outlet downcomers, and provided also that no derating is made on account of surface tension being less than 20 dynes.

Thus the required cap area and the resulting vapor velocities in the region above the caps are not based on the maximum loading, nor on the minimum, but represent an intermediate case somewhat comparable with the Souders and Brown ratings. But contrary to that method, vapor-handling capacity is not derated on account of the low surface tension characteristic of hydrocarbons and organic compounds because actual performance with the light hydrocarbons justifies the higher ratings. But though surface tension does not seem to have any adverse effect on entrainment, the following properties or conditions are considered to have an influence:

1. High viscosity of the liquid phase in the range of 10 to 100 centipoises and above is a cause of foam. The presence of excess dissolved light components, as in the asphalt strippers of



Table 1.—Tray Constants

$H''$ , in.	$K_1$	$K_2$	$f_a$
18	.233	840	2,020
24	.268	1040	2,500
30	.323	1160	2,800

propane deasphalting plants, increases the difficulty, no doubt because of the small bubbles and viscous films (2).

2. High boiling aromatic fractions apparently have a greater tendency to foam than do the straight-run fractions (8), and straight-run fractions greater than water.

3. Colloidal or other suspended matter (mineral, waxy, or asphaltic) or a second emulsified liquid phase is considered objectionable.

4. Excessive buildup of liquid due to insufficient liquid-handling capacity culminates in cycling of the liquid to the tray above.

5. Insufficient liquid on the tray (a condition caused by a relatively small amount of reflux together with a weir arrangement or setting insufficient to retain the liquid) means the disappearance of the usual zone of suspended droplets and the appearance of jets of atomized liquid of such fine droplet size as to be carried along to the tray above.

Each of the special cases cited requires an appropriate method of handling. Sometimes it is possible to adjust an operating condition so as to diminish or entirely eliminate the foaming condition. If not, the design must be adjusted to suit the prevailing condition and especially the weirs and downcomers must be made suitable for the liquid. So it is to be presumed that the remaining cause of entrainment is vapor loading or velocity.

It is now considered that entrainment is due to the kinetic influence of the rising vapor in the region above the caps. The rate of entrainment, gal./min./sq.ft., of installed cap area is considered as a function of the relative vapor loading,  $a/A$ . Table 2 shows the relation.

In distillations conducted under vacuum only a small amount of distillate is available for refluxing the plates, which are of large cross section. Therefore only a little reflux is available per square foot of installed cap area, and it follows that the entrainment must be kept quite small to avoid nullifying the desired effect of the reflux; or conversely, that if the vapor loading is increased, the reflux should also be increased enough to wash back the additional entrainment. Thus, if in a vacuum distillation the relative vapor loading is increased twofold, from 0.4 to 0.8, then the reflux should be increased about eightfold in order to dilute the entrainment to the same relative concentration on the trays below.

But if there is a large excess of reflux, the entrainment is quickly di-

luted and washed back. Its worst effects are then using up liquid capacity and increasing pressure drop. In order to prevent tower flooding, the liquid loading in an operating unit must be reduced even at the expense of reflux ratio. But in the design of a new tower the liquid loading would not be decreased, as it is set by fractionation requirements; but the liquid loading should be increased by an amount equal to the entrained liquid, and the resulting total liquid quantity used in selecting the number and size of downcomers.

#### Liquid Cross Flow

The movement of liquid across a tray may be through clearances provided under the skirts of the caps, or through openings or channels left between caps, or, most generally of all, across the region above the caps. The liquid may be aerated to various degrees or assisted in its forward movement by stepped trays or by directed jets of vapor. It is thus seen that there is no single or simple mechanism of flow on which to base an equation, as is done for vapor, and so it is necessary to proceed by rule of thumb—make approximations first and thereafter correct them as new experience is obtained.

One rule of design may be stated as follows: the distance across the cap area in the direction of flow should be proportional to the cap area and inversely proportional to the liquid flow. If this distance is designated  $l_1$  (ft.) and a suitable factor  $2f_b$  for the flow in gal./min. (including entrainment), is included, this rule becomes

$$l_1 = \frac{a}{2f_b(\text{gal./min.})} \quad (2)$$

If the dimension parallel to the weir and transverse to the flow is denoted by  $l_2$  (ft.), then an alternate form of the preceding rule is

$$l_2 = \frac{a}{l_1} = 2f_b(\text{gal./min.}) \quad (2a)$$

It is plain from the two forms considered together that the cap area should be arranged and proportioned on the tray in such a way as to permit the installation of downcomers along the margins, with the inlet downcomer at one side and the outlet downcomer at the opposite side. Furthermore, if  $l_2$

is found to exceed greatly  $l_1$ , then a multipass tray layout is indicated, that is, a plurality of downcomers in the direction of flow.

Another rule of design deals with the provision of area needed on account of liquid. It may be stated as follows: the downcomer area allotted for handling liquid should be proportional to the liquid flow. If the respective areas in which inlet and outlet downcomers are to be located are designated  $b$  and  $c$  (sq.ft.), then

$$b = c = f_b(\text{gal./min.}) \quad (3)$$

The factor  $f_a$  used for the required cap area is a function of tray spacing, and so also is the factor  $f_b$ , which is taken inversely proportional to the tray spacing  $H''$ . The inverse proportionality corresponds to or is derivable from the idea of a fixed residence time (1) in the downcomer, that is, from about 7 to 10 sec., depending upon the available specific-gravity differential. Table 3, p. 118, shows the numerical values of  $f_b$  as influenced by the two factors, tray spacing and specific-gravity differential. An increasing influence for the latter in reducing the liquid-handling capacity is shown as the critical point is approached. At the other extreme water can be transported across the tray and in the downpipes at about twice the best rate for hydrocarbons, at least in the absence of foam promoters.

To summarize the rules, the first, represented by Equation (2), has for its purpose the avoidance of an excessive hydraulic gradient; whereas the second, expressed in Equation (3), refers to the need for an area sufficient to permit subsidence of the liquid from the aerated phase coming from the region above the caps. To illustrate these rules, a design case with trays on 24-in. centers with a required cap area found to be 30 sq.ft. and with a liquid loading of 750 gal./min. including entrainment may be assumed. A value of .008 is used for  $f_b$ . Then from Equation (2) it is found that the distance across the cap area from inlet to outlet weir should be 2.5 ft., and from Equation (2a) the dimension of the cap-area transverse to the flow of liquid is 12 ft. Thus a two-pass tray layout is indicated with the cap area divided into two regions, one on each side of the central downcomer and each having dimensions of about 2.5 ft. across by 6.0 ft. avg. length. From Equation (3) it is found that the center downcomer should account for about 6 sq.ft., and the two side downcomers also total 6 sq.ft., or are 3 sq.ft. each.

The installed downcomer areas are called  $B$  and  $C$  for inlet and outlet, and like the installed cap area, refer to

Table 2.—Entrainment

Typical Operation	$a/A$	gal./min. A
Dry vacuum, low-pressure drop . . . . .	.4	.03
Typical wet vacuum distillation . . . . .	.6	.1
Flash zone of crude pipe still . . . . .	.8	.3
Basis for design capacity . . . . .	1.0	1
Refluxed plates, atmospheric tower . . . . .	1.1	2
Refluxed plates, butane splitter . . . . .	1.2	5
Stripping section, butane splitter . . . . .	1.25	10
Ultimate capacity . . . . .	1.3	25

surfaces on a specific tray layout, as in Figure 1. Thus, if  $L_1$  (ft.) is the distance across the installed cap area (hence equal to the number of rows crossed times the distance between rows) and if  $L_2$  is the length of the average or typical row crossed by the liquid (which will ordinarily be the second row from the side segment), then the areas (sq.ft.) are

$$B = C = .5L_2 = .5A/L_1 \quad (4)$$

#### Edge Losses

In the interpretation of any specific tray layout for the evaluation of  $A$ ,  $B$ , and  $C$ , it is highly desirable to do so consistently from one case to the next so that designs will be based upon an accumulation of experience, including towers operating at ultimate as well as at design capacity. Past experience is the best guide in resolving the difficulties that might be encountered in selecting the most appropriate values for the installed areas, and by difference the remaining edge losses  $X$ , sq.ft. About 15% of the total tower cross section  $Y$ , sq.ft. is standard edge loss. Less efficient layouts might result in edge losses as high as 20%, and in more efficient layouts these might be reduced to 10%. The edge losses would be evidenced in a tower at ultimate capacity by local regions with relatively low rate of entrainment to which it would be advantageous to divert additional vapor or liquid. That is the real test—the advantage to be gained by a redistribution of the flow of vapor and liquid to those regions in which the local superficial area is not fully exploited in the interest of capacity. It is in this sense that the installed areas for liquid handling should be approached. To the extent that marginal areas prepare settled liquid for passage through the downpipe, they are useful for liquid handling, and subject to experience, are to be classified as installed area rather than as edge losses.

#### Downpipe and Weir

Likewise the dimensions of the weir and of the downpipe, as long as they are kept within the proved range of experience, may be selected according to any reasonable rule, being made larger or smaller as desired. Thus, if

the downcomer is at its maximum size with the weir immediately adjacent to the cap area, it receives a relatively more frothy mixture and in the end has no greater capacity than a design with the weir set back from the cap area, with a disengaging space between, and with a downpipe of reduced cross section. In connection with the size and shape of the downpipe, reference is made to the survey and discussion by Nelson (7).

Other points having a bearing on the collection of liquid are: (1) the extent to which open channels through the caps assist cross flow and (2) the extent to which vertical walls or baffle plates receive the impingement of froth and aid the entry of liquid into the downpipes. Radical departures from ordinary practice would call for a closer examination of these points.

The minimum height under the downcomer, that is, the clearance between the bottom of the downcomer and the top of the plate and likewise the clearance between the downcomer and any inlet weir in front of it, is usually selected in the range of about 2 or 3 in., or more, generally so as to satisfy a specified velocity requirement. Velocities of from 1 to 2 ft./sec. under downcomers have been observed at high liquid loadings, but for new design a lower velocity should be selected, say 0.7 ft./sec. This can be accomplished by making the free area under the downcomer equal to 40% of  $B$  as defined in Equation (4).

The open cross section of the downpipe  $S$ , sq.ft. may be anywhere from 50 to 100% of the installed area with which it is associated, the balance being disengaging space. Thus, in the illustration in which a center downcomer area of 6 sq.ft. was found and in which the tower diameter was 8 ft., the downpipe might be 8 ft. long  $\times$  9 in. outside (say 8½ in. inside), thus using

100% of the installed area; or it might be constructed as two boxes, each 3 ft. long  $\times$  6 in. I.D. Thus 50% of the installed area is used, and the other 50% is accounted for by associated disengaging areas. The selection might be based either on the use of the downcomer as a beam for support of the tray or on a preference for the center passageway between downpipes as a convenience when work is to be done inside the towers. The side downpipes may also be varied in cross section, yet without impairing the tray hydraulics. In some designs the inside of the downcomer is stepped or sloped, the open area at the top being available for disengaging and the constricted area at the bottom still being sufficient for liquid flow. One reason for using a sloped downcomer is to leave room on the next tray below for an inlet weir or at least a bar or a step to cause the liquid to flow up and over the near caps, which, relieved of the rush of liquid around them, can then bubble more freely.

The velocities in downcomers sized according to these rules are reasonable not only for the design rates but even for relative liquid loadings ( $b/B$ ) about 250% of design, provided, of course, that the vapor rate is diminished enough to permit moving the liquid across the tray to the downcomers. The design velocities in the downpipes and the ultimate obtainable at 250% of design are stated in Table 4, shown below.

In comparison with the range of velocities in Table 4, and in comparison with the particular value of .28 ft./sec. for a full-size downpipe at 100% of design capacity, Nelson (7) recommends 0.16 to 0.33 ft./sec., and Huntington (4) recommends 0.5 ft./sec. as a maximum. But in the case of downpipes with which an adequate disengaging space is associated, velocities above 1.0 ft./sec. are not unusual; and in one instance (a high pressure absorber with trays on 22-in. centers) an ultimate velocity of 1.4 ft./sec. was obtained.

The weir is usually about 2 in. high. It may be made higher or lower depending upon (1) nearness to the cap region and (2) the liquid loading. In the case of low liquid rates it is advisable to install a vertical plate upstream of the weir so as to retain the necessary working quantity of liquid in the aerated

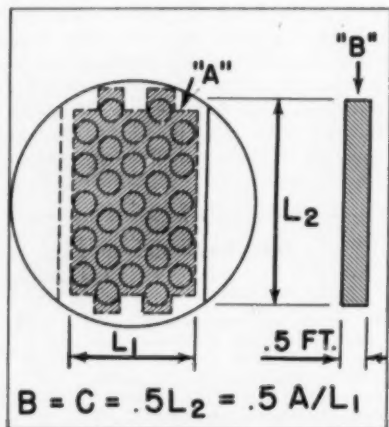


Fig. 1. Installed downcomer area.

Table 3.—Values of  $f_s$

$S_L - S_V$	$H'' = 18$ in.	$H'' = 24$ in.	$H'' = 30$ in.
Water	.0053	.0040	.0032
.60	.0107	.0080	.0064
.50	.0108	.0081	.0065
.45	.0112	.0084	.0067
.40	.0120	.0090	.0072
.35	.0133	.0100	.0080
.30	.0160	.0120	.0096

Table 4.—Velocities in Down Pipes

$b/B$	$H''$ , in.	$S = B$	$S = .5B$
1.00	18	.21	.42
	24	.28	.56
	30	.35	.70
2.50	18	.52	1.04
	24	.70	1.4
	30	.87	1.7

phase or, alternatively, the cross section of the downpipe may be reduced so as to limit the entrance of aerated phase.

#### Interaction Between Vapor and Liquid

When absorbers and fractionators are tested to ultimate capacity and at various ratios of liquid to vapor, it is generally found that the maximum vapor capacity is attained with lower liquid rates and that vapor capacity falls off as the liquid rate is increased. When the maximum allowable vapor rate is plotted as a function of the liquid rate, the resulting curve is suggestive of a section or quadrant of an ellipse. Expressing this in the appropriate mathematical form, using the relative loadings, and selecting numerical factors to fit the observations, one finds the general expression for ultimate capacity:

$$\left(\frac{a}{1.2A}\right)^2 + \left(\frac{b}{1.8B}\right)^2 = 1.30^2 \quad (5)$$

At design capacity the numerical result is

$$\left(\frac{1}{1.2}\right)^2 + \left(\frac{1}{1.8}\right)^2 = .694 + .308 = 1.00 \quad (5a)$$

For various combinations of relative vapor and liquid loading, the capacity factor, expressed as a fraction of design capacity or as a ratio of areas  $y/Y$ , then becomes

Capacity Factor =  $y/Y$

$$= \sqrt{\left(\frac{a}{1.2A}\right)^2 + \left(\frac{b}{1.8B}\right)^2} \quad (5b)$$

The range of combinations of relative vapor and liquid loadings at design capacity (capacity factor = 1.00) and at ultimate capacity (capacity factor = 1.30) are shown below.

It is convenient to express results, whether they be those of design calculations or those of performance tests, in terms of the capacity factor. The interaction between vapor and liquid is then accounted for. But there are also other things to consider, such as plate stability (3) and the retention of a working level of liquid on the tray. The accumulation of sufficient liquid on the trays is almost automatically assured if the installed areas are equal to the respective required areas for vapor and liquid, or at least if the disproportion is

not too great. It is when the disproportion is excessive that faulty types of operation can be expected. A capacity factor in excess of 1.30 almost automatically results in tower flooding, and for viscous, foaming, or dirty stocks, a still earlier carry-over is indicated. Excessive cross-flow liquid rates in combination with relatively low-vapor velocity in the risers of the caps, will result in an unstable plate; whereas the other extreme of too little cross flow in combination with high vapor rates and large downcomers is equally unsatisfactory. Each of these extremes should be avoided. Finally, it should be mentioned that in new design the selection of a capacity factor of 1.0 does not of itself assure the best all-round unit, as a final review of the engineering and economic background might lead to preference for some other selection in the range of 0.8 to 1.2 for the capacity factor.

#### Pressure Drop

From the point of view of new design, there are several reasons which from time to time make it desirable to consider pressure drop. For example, a minimum pressure drop might be desired, as in the case of vacuum distillation; or the specific tray layout may have an installed cap area considerably greater or smaller than the required cap area. It is usual therefore to select the cap spacing, size, and internal dimensions with a view to the required duty. The ratio  $R/A$  of installed riser area  $R$ , sq.ft., to installed cap area varies from a minimum of about 0.10 to a maximum of about 0.20, with 0.15 being a good average value. The internal construction of caps is likewise varied from one extreme of intentionally restricting the flow to the other of the best possible streamlining. It seems that a simple cap of sturdy construction, neither too high or too low, with the internal passages of moderate roundness and uniform cross section, is to be preferred. Caps may be circular, oval, or rectangular; and the pattern on which they are laid out may be rectangular or diagonal, or even in some cases irregular to reduce edge losses.

For vacuum distillation a close cap

spacing is desirable so that pressure drop will be at minimum, and  $R/A$  of about 0.20 should be selected (5). Also,  $a/A$  will be in its low range, from 0.4 to 0.6, to keep entrainment at a minimum. Plate stability automatically results from the low liquid cross flows usually found or is obtained in the case of higher flows by stepping the plate and installing intermediate weirs. For the usual atmospheric and pressure distillations  $R/A$  should be about 0.15 with  $a/A$  of, say 1.0, as a characteristic value. But if  $a/A$  is less than 1.0 and especially if the relative liquid loading  $b/B$  is in the high range of 1.5 or 2.0, then it is desirable that  $R/A$  approach 0.10 as a lower limit, thus improving plate stability not only by forcing all caps into more uniform activity but also by permitting wider lanes for the passage of liquid between caps and by permitting subsidence of aerated phase upstream of the weir. Thus a capacity advantage equivalent to increasing  $B$  at the expense of  $A$  is gained. It is for dealing with these situations that a pressure-drop relation is desirable.

Table 6.—Velocity Heads, Dry Plate

	Min.	Max.
Entrance .....	.5	1
Reversal .....	1.5	2
Exit .....	1	1
$k$ , Total .....	3	4

The dry-plate pressure drop may be built from velocity heads (6) as follows: the cross section through the riser and reversal area is considered constant, and the successive velocity heads are additive.

The friction of the vapor against the tray as it turns and rises is neglected as is the velocity of approach from the tray below because these two effects are minor and tend to cancel. An average cap, intermediate between the most and the least streamlined, might then be expected to show a dry-plate pressure drop of 3.5 velocity heads. The equivalent orifice coefficient is then

$$1/\sqrt{3.5} = .535,$$

which compares with the value 0.533 found for an experimental cap of a type used in some installations of field gasoline plants (10). The dry-plate pressure drop (feet of vapor) is then

$$F = ku_R^2/2g, \quad (6)$$

or, in terms of relative vapor rate and of inches of liquid and with 3.5 for  $k$ , the dry-plate pressure drop is

$$F_R'' = 0.65K_L^2(a/R)^2, \quad (6a)$$

The wet-tray pressure drop is ob-

Table 5.—Relative Vapor and Liquid Loadings

Typical Condition	(b/B)		
	(a/A)	$y/Y = 1.0$	$y/Y = 1.30$
Unstable plate .....	.4	1.70	2.26
Poor aeration .....	.6	1.56	2.16
Operable .....	.8	1.34	2.01
Good tray action .....	1.0	1.00	1.80
Good tray action .....	1.1	.72	1.66
Some entrainment .....	1.2	.60	1.50
Heavy entrainment .....	1.25	....	1.41
Ultimate vapor loading .....	1.30	....	1.30



tained by adding a first increment of about 1.5 in. of liquid, which might be considered to represent the submergence at zero vapor flow but which is more realistically described as the suspended liquid in an aerated phase of about minimum depth or density at low liquid cross flow. The aerated phase might be divided into a lower denser region, say one third liquid and 3 in. high, and an upper less dense region averaging one tenth liquid and, say 5 in. high, giving a total depth of 8 in. and an added pressure drop of 1.5 in.

Table 7.—Typical Pressure Drop

Service	a/A	R/A	b/B	h'' in. liq.
Dry vacuum	.4	.20	.4	2.1
Wet vacuum	.6	.20	.6	2.9
Atmospheric	.8	.20	.8	4.0
Atmospheric	1.0	.15	1.0	5.7

The second increment of wet-tray pressure drop is due to liquid cross flow, as excess submergence at the inlet side of the tray, as excess suspended liquid in the aerated phase, or as a cause of poor vapor distribution and resulting excess vapor friction through the caps at the outlet end of the tray. Then relative liquid loading (squared) is the principal variable, with a multiplier of  $A/(A-3R)$  chosen to include the benefit of wide cap spacing in promoting uniformity of vapor distribution and thereby reducing the tendency of liquid to accumulate near the inlet.

A third increment of pressure drop, from 2 to 5 in. of liquid, resulting from excessive entrainment and liquid carry-over as ultimate capacity is reached, is one of the evidences of this condition; but as there is little practical benefit to be gained by incorporating this last increment, it is omitted from the equation.

Wet-tray pressure drop ( $h''$ , in. of liquid) is the total of the several increments of pressure drop already considered.

$$h'' = .65 K_1^2 \left( \frac{a}{R} \right)^2 + \frac{A}{(A-3R)} \left( \frac{b}{B} \right)^2 + 1.5 \quad (7)$$

In vacuum distillations and in some atmospheric distillations also, the need for low over-all pressure drop leads naturally to the selection of a larger riser area and a low relative vapor rate. The relative liquid loading is also kept low for plate stability. The corresponding pressure drop can then be found by Equation (7). A tray spacing of 24 in. is assumed, with 0.288 used for  $K_1$ .

At ultimate capacity the pressure drop can be calculated for various ratios

of vapor to liquid with riser area a variable. The riser area that results in the least pressure drop is preferred. Again 24-in. tray centers are assumed.

Table 8 shows qualitatively that the effect of riser area has been incorporated to about the right degree in Equation (7), as the lowest pressure drop is seen to correspond with about the right percentage of riser area as known from experience. Also, the table shows that a good general rule for the sizing of riser area is to relate it to the required cap area so that  $R/a$  is approximately 0.15 at design conditions.

The table also illustrates a rather uniform pressure drop of about 10 in. of liquid, or more generally 40% of the tray spacing to be expected at ultimate capacity, that is, exclusive of the last sudden increment of 10 or 20% at flooding conditions. This suggests rearranging Equation (7) so as to show its close analogy with Equation (5); that is,

$$\left( \frac{a}{1.2A} \right)^2 + \frac{R/A}{.94K_1^2} \left( \frac{R}{A-3R} \right) \left( \frac{b}{B} \right)^2 = \frac{h'' - 1.5}{.94K_1^2} \left( \frac{R}{A} \right)^2 \quad (7a)$$

A further correspondence is obtained by setting  $K_1 = 0.288$  and  $R/A = 0.123$ , giving

$$\left( \frac{a}{1.2A} \right)^2 + \left( \frac{b}{1.8B} \right)^2 = \frac{h'' - 1.5}{5.15} \quad (7b)$$

Finally, it is found that letting  $h'' = 10.2$  will give the numerical result 1.69, that is, 1.3<sup>2</sup>; and so for the usual case of flooding, Equation (7b) reduces to identify with Equation (5). Thus one equation may be derived from or explained in terms of the other and vice versa, the whole being on a consistent basis with respect to ultimate capacity and the pressure drop observed as this condition is approached.

#### Example 1.

To illustrate the use of the method two examples have been chosen, the first dealing with the selection of a tray layout for a specified duty and the second with the estimation of the ultimate capacity of the tray.

In Example 1 the design conditions are given,

Table 8.—Limiting Pressure Drop

		h'', in. of Liquid				
		R/A =				
a/A	b/B	.10	.13	.20	R/a = .15	
.4	2.26	9.7*	11.2	14.5	10.1	
.6	2.16	10.1*	10.9	13.6	10.3	
.8	2.01	10.7	10.3*	12.5	10.2*	
1.0	1.80	11.5	9.8*	10.9	9.3*	
1.1	1.66	11.9	9.4*	10.0	9.4*	
1.2	1.50	12.5	9.0*	9.0*	8.8*	
1.3	1.30	13.0	8.7	8.0*	8.0*	

\* Preferred selection.

that is, the weight rates and densities of vapor and liquid. The conditions are such as might be found in the stripping section of a naphtha fractionator, perhaps close to the reboiler and at a point of maximum loading. It is further predicated that the sizing will be sufficiently generous so that at the design rates that zone of the tower will be loaded not to the verge of flooding, but only to about 80% of ultimate capacity as limited by flooding.

The first steps of the calculations lead to the required cap area  $a$  and then to the required downcomer areas  $b$  and  $c$ . An allowance of 15% for edge losses is added, and the total is 23.8 sq.ft., which is the tower cross section required by the statement of the problem. As a diameter of 5.5 ft. would provide the required tower cross section, this dimension is accordingly selected for the design.

Next comes the selection of the number of caps, the pattern of their arrangement on the tray, and the details of their internal construction. There a high degree of conformity with local practice may be desirable or even requisite. Let it be assumed, for example, that in the present case a standard cap is to be used with a 6-in. O.D. for lightweight construction or 6½ in. for cast iron, with a riser I.D. of 4 in. and an internal cross section of .087 sq.ft. throughout the vapor passage. The number of these caps calculated in accordance with the principle illustrated in Table 8 (whereby a total riser area equal to 15% of the required cap area is about the optimum) is found to be 26.2, which is, of course, nothing more than an approximation. It would probably be satisfactory to use as few as 22, or as many as 32. But let the number actually chosen be 27 and the arrangement of them on the tray be as shown in Figure 1. The center-to-center distances between the caps (10 in.) and rows (8½ in.) are selected so that the installed cap area (number of caps times unit area) is equal to 15.2 sq.ft., the same as the required cap area. Thus at the design vapor rate the ratio  $a/A$  would be unity, and the degree of entrainment as a function of this ratio would be well within acceptable limits.

The dimension  $L_2$  transverse to the flow of liquid is that of the typical row crossed by the liquid which, in this case, contains six caps on 10-in. centers. The length is 5 ft., and the installed downcomer areas, inlet and outlet, are 2.5 sq. ft. each, the same as the required downcomer areas already found. Thus at the design liquid rates the ratios  $b/B$  and  $c/C$  are also equal to unity, which would assure moderate hydraulic gradients and satisfactory flow of liquid across the tray.

The edge loss  $X$  is found by difference to be 3.6 sq.ft., or 15.1% of the tower cross section, which, as it is right in the middle of the range of from 10 to 20% considered to be normal, signifies that the division of the tray area into the useful parts  $A$ ,  $B$ , and  $C$  and the nonuseful part  $X$  has not been unjustifiably optimistic.

Finally, the weir dimensions and downcomer clearances are fixed and the velocities checked to make sure that they are not excessive for the anticipated flow of liquid. (The calculations are shown.)



### Example 2.

This example illustrates a calculation of ultimate vapor and liquid capacity in which it is assumed that the previously selected tray is operated at a vapor rate 20% in excess of the design rate and that the liquid rate is then increased until the tower is at ultimate vapor and liquid capacity. That is, the vapor and liquid rates would, when substituted in Equations (1b) and (3), yield required areas *a* and *b* about 30% in excess of the installed areas *A* and *B* or, more precisely, would satisfy the criterion for ultimate capacity as given by Equation (5). The allowance for entrainment, read from Table 2, shows that about 5 gal./min.(sq.ft.) is to be expected, which would use up a part of the downcomer capacity and reduce that available for net liquid down the tower. Thus, although the gross quantity of liquid is 50% greater than the same quantity at design conditions, the net increase in liquid is only 27% after correction for the considerable increase in entrainment. But the bottoms rate as represented by the difference between vapor and liquid is now 37% in excess of design, or more than either the vapor or the liquid. Thus, the charge rate could also be greater by this amount provided that the tray efficiency actually realized was sufficiently higher than that assumed in the design to offset the less favorable reflux ratio and provided also that other factors did not limit.

#### Tray Efficiency

In general, tray efficiency is influenced both by operating conditions and by tray design. Of all the variables that might be considered, four have been selected as sufficient to establish efficiencies within about the usual range typical of various services.

Murphree Efficiency (%)

$$= 100 \left( \frac{a}{2b + 6R} \right) \left( \frac{\text{net liquid}}{\text{total liquid}} \right) \quad (8)$$

The variables in this equation and the tray behavior tendencies that they are intended to represent, follow.

As the vapor flow through a tray increases, it suspends a greater quantity of liquid and exposes a greater interfacial area, thus promoting the exchange of

### Example 1.—Calculations Leading to Tray Layout

		Units
<b>Design Conditions:</b>		
Vapor Rate	59,000	lb./hr.
Av. mole wt.	100	
Abs. temperature	730	° R.
Abs. pressure	24.7	lb./sq.in.
Gas law factor	.95	
Density	.332	lb./cu.ft.
Liquid Rate	100,000	lb./hr.
Equivalent volume	295	gal./min.
Density	42.2	lb./cu.ft.
<b>Selection of Tray Dimensions:</b>		
Tray centers	24	in.
Factor (from Table 3)	.008	
Constant (from Table 1)	1,040	
Radical (Eq. (1a))	$\sqrt{41.9 \times .332} =$	3.73
Entrainment (from Table 2)	$=$	1 gal./min.(sq.ft.).
<b>Bubble Caps</b>		
Required cap area (Eq. (1b))	$a = 59,000/1,040 \times 3.73 =$	15.2 sq.ft.
Inside cross section/4-in. I.D. riser	.087	sq.ft.
Approximate number of caps required	$= .15 \times 15.2/.087 =$	26.2
<b>Downcomers (assume liquid nonfoaming).</b>		
Required downcomer area [Eq. (3)]		
$b = c = .008 \times (295 + 1 \times 15) =$	2.5	sq.ft.
Dimension parallel to weir (Eq. (2a))	5.0	ft.
Required total area (with 15% edge loss)	$(15.2 + 2.5 + 2.5)/.85 =$	23.8 sq.ft.
Selected tower (tray) diameter	$D =$	5.3 ft.
Total superficial cross section	$Y =$	23.8 sq.ft.
Tray layout selected same as Fig. 1		
Total number of caps to be installed	27	
Center-to-center distance, caps in rows	10	in.
Center-to-center distance, rows	8.125	in.
<b>Installed Cap Area</b>		
$A = 27 \times 10 \times 8.125/144 =$	15.2	sq.ft.
<b>Installed Downcomer Area</b>		
(Take second row from weir as average row)		
$B = .5 \quad L_2 = .5 \times 6 \times 10/12 =$	2.5	sq.ft.
$C = 8$	2.5	sq.ft.
$Y = .785 \times 5.3^2 =$	23.8	sq.ft.
$X = 23.8 - 15.2 - 2.5 - 2.5 =$	3.6	sq.ft.
<b>Check Edge Loss:</b>		
$X/Y = 15.1\%$ , which is about average.		
<b>Selection of Further Tray Details:</b>		
Risers 4-in. I.D. $\times$ 2 to 3 in. high	$R =$	2.36 sq.ft.
Caps 6 to 6½ in. O.D. (say 6½ in.)		
Clearance, from center-line of nearest cap to weir or downcomer, also 6½ in.		
Side segment available for downcomer, 10 in.		
Downpipe area, inside cross section	$S =$	1.75 sq.ft.
Check: Velocity in downpipe free area	$=$	.4 ft./sec.
Weir length then found to be 45 in.		
Clearance under downcomer 3 in.		
Check: Velocity in downcomer exit area	$=$	.74 ft./sec.
Weir height 1 to 3 in. (say 2 in.).		

### Example 2.—Ultimate Vapor and Liquid Capacity

Operating Conditions at Ultimate Capacity	Units	Required Downcomer Area (from Eq. (5)).	
(For purpose of illustration, assume a case in which the vapor rate is 20% higher than in Example 1, and in which the corresponding liquid rate at ultimate capacity is to be found by calculation.)		$b = 2.5 \times 1.8 \sqrt{1.69 - (1.20/1.2)^2} =$	3.73 sq.ft.
Vapor rate	70,800 lb./hr.	Total liquid	$3.73/.008 = 466$ gal./min.
Density	.332 lb./cu.ft.	Entrainment	$.5 \times 18.2 = 91$ gal./min.
Liquid rate (to be found)		Net liquid	$466 - 91 = 375$ gal./min.
Density	42.2 lb./cu.ft.		$375 \times 60 \times 42.2/7.48 = 127,000$ lb./hr.
<b>Tray Dimensions and Details</b>		<b>Comparison, Ultimate Capacity vs. Design</b>	
(Assume all tray dimensions and details are as already selected under Example 1.)		Vapor below feed	$70,800/59,000 = 120$ %
<b>Calculations</b>		Net liquid below feed	$127,000/100,000 = 127$ %
Required Cap Area $a = 70,800/1,040 \times 3.73 =$	18.2 sq.ft.	Bottoms product	$56,200/41,000 = 137$ %
		<b>Pressure Drop (per tray) at Ultimate Capacity</b>	
		Dry tray	$.65 \times .083 \times 59.5 = 3.2$ in.
		Aeration	$= 1.5$ in.
		Cross flow	$2.23 \times 15.2/8.12 = 4.2$ in.
			8.9 in.

components between the vapor and liquid phases. For this reason  $a$ , the required cap area, has been incorporated as a factor.

But as vapor rate increases, so does entrainment, especially at the higher vapor rates. This is illustrated in Table 2, which shows entrainment vs. relative vapor loading  $a/A$ . The entrainment is added to the net liquid to obtain the total liquid, and the ratio of the two is then used as a factor in the equation. It is close to unity when the entrainment is a negligible proportion of the total liquid, but in the opposite case of an excessively large degree of entrainment relative to the net liquid, it portrays a corresponding decline in tray efficiency.

As the flow of liquid increases, the residence time on the tray decreases in inverse proportion. If the residence time is insufficient to permit a reasonably close approach to equilibrium, the tray efficiency decreases. In an extreme case the flow of liquid might be so great relative to the vapor that not all of the liquid would be dispersed and brought into effective contact with the vapor, and so any additional flow of liquid would in effect be by-passed, with resulting decline in efficiency. Accordingly a term  $2b$ , proportional to the liquid flow, has been included in the denominator.

Finally the total riser area is brought in by means of a term  $6R$ , which is additive to  $2b$  in the denominator. A good

value for  $R$  is about 15% of  $a$ , and so  $6R$  might normally be about 90% of  $a$ . Lower values cause the dry-cap pressure drop to increase, thus bringing about a more uniform distribution of vapor and an improvement in the Murphree efficiency (under certain conditions to values even in excess of 100%). Conversely, excessive riser area can result in uneven vapor distribution and permit local by-passing of the liquid, or even dumping, with corresponding decline in efficiency.

Thus four principal variables can be distinguished, although there is some choice as to which they shall be; for example,  $a$ ,  $A$ ,  $R$  and net liquid, or  $a$ ,  $b$ ,  $R$  and entrainment, etc. In any case, four variables tend to make a graphical presentation of Equation (8) rather unsatisfactory, and Table 9 has been set up to show numerical values of tray efficiency calculated by means of Equation (8) and the influence of each of the variables.

The tray efficiencies are shown in the extreme right-hand column of Table 9. They range from as high as 120% to as low as 9%. The various cases selected for consideration have been collected in nine groups, the general trend being in the direction of increasing liquid, decreasing vapor. Groups I-IV represent trays having relatively more caps, and so the distance across  $L_1$  is 8.0 ft.; in Group V this distance has been reduced to 3.5 ft.; in Group VI to 1.25

ft., or about 2 rows of caps; and finally, in Groups VII-IX the distance across is 0.5 ft., which is sufficient for only a single row of caps.

In Group I the riser area is quite large (20%) such as might be selected in order to keep pressure drop at a minimum. At low vapor and liquid rates, which might be necessary for vacuum distillation, the calculated efficiencies are low; but at higher loadings the efficiencies pick up, to a maximum of 66%, and then decrease again because of entrainment.

Group II shows that with a riser area of about 15% the tray efficiency would increase. The calculated values range up to as high as 85% at the design loading, which is believed to be fairly typical of many services.

Group III shows what might be expected with a still further decrease in the riser area (down to 10%). The maximum efficiency of 120% corresponds to an almost ideal case in which a concentration gradient is maintained along the liquid path from inlet to outlet and in which the rates are sufficient to maintain uniform distribution, yet without too much entrainment. The dry-cap pressure drop that corresponds to this case is rather high. It might easily become a limitation to tower capacity.

The combination of a relatively high liquid flow with a low dry-cap pressure drop gives an unstable plate, which was indicated previously in Table 5. In

Table 9.—Tray Efficiencies Calculated by Equation (8)

Group	A	B	$L_1$	R					Liquid, gals./min.			Eff., %
					$\frac{a}{A}$	$\frac{b}{B}$	$\frac{a}{a+b}$	$\frac{b}{a+b}$	Total	Entrained	Net	
I	80	5	8.0	16	.4	.4	32	2	250	2	248	32
					.6	.6	48	3	375	8	367	46
					.8	.8	64	4	500	24	476	59
					1.0	1.0	80	5	625	80	545	66
					1.1	1.2	88	6	750	160	590	64
					1.2	1.5	96	7.5	940	400	540	50
II	80	5	8.0	12	.8	.8	64	4	500	24	476	76
					1.0	1.0	80	5	625	80	545	85
					1.1	1.2	88	6	750	160	590	82
III	80	5	8.0	8	.8	.8	64	4	500	24	476	109
					1.0	1.0	80	5	625	80	545	120
					1.1	1.2	88	6	750	160	590	115
IV	80	5	8.0	16	.4	1.70	32	8.5	1060	2	1058	28
				12	.4	1.70	32	8.5	1060	2	1058	36
				8	.4	1.70	32	8.5	1060	2	1058	49
				4	.4	1.70	32	8.5	1060	2	1058	78
V	70	10	3.5	10.5	.8	.8	56	8	1000	21	979	69
					1.0	1.0	70	10	1250	70	1180	80
					1.1	1.2	77	12	1500	140	1360	80
VI	50	20	1.25	7.5	.8	.8	40	16	2000	15	1985	52
					1.0	1.0	50	20	2500	50	2450	58
					1.1	1.2	55	24	3000	100	2900	57
VII	30	30	.5	4.5	.8	.8	24	24	3000	9	2991	32
					1.0	1.0	30	30	3750	30	3720	34
					1.1	1.2	33	33	4125	60	4065	34
VIII	30	30	.5	6	.4	1.0	12	30	3750	1	3749	12
				4.5	.4	1.0	12	30	3750	1	3749	14
				3	.4	1.0	12	30	3750	1	3749	15
				2	.4	1.0	12	30	3750	1	3749	17
IX	30	30	.5	6	.4	1.70	12	51	6380	1	6379	9
				4.5	.4	1.70	12	51	6380	1	6379	9
				3	.4	1.70	12	51	6380	1	6379	10
				2	.4	1.70	12	51	6380	1	6379	11

Group IV the riser area is shown reduced by steps; the calculated improvement in tray efficiency is from a low of 28% to a high of 78%, after utilization of all of the available pressure drop for distributing the vapor into the liquid.

Groups V-VII illustrate reductions in cap area and increases in downcomers such as would be typical for increasing ratios of liquid to vapor. The distances  $L$  across the caps in the direction of flow are 3.5, 1.25, and 0.5 ft. respectively, for which the corresponding number of rows of caps crossed by the liquid might be 4, 2, and 1. The typical tray efficiencies corresponding thereto are 80, 58, and 34% when at design capacity.

For still further increases in the ratio of liquid to vapor, Groups VIII and IX show further reductions in tray efficiency, first to 15% and finally to 10%. Such high ratios of liquid to vapor are encountered when the relative volatility of the liquid is quite low compared to that of the vapor; in such circumstances it is usual to find low tray efficiencies of approximately the value shown.

Thus tray hydraulics can be used to account for the general trend observable in tray efficiencies when comparing one service with another, especially with respect to the liquid-to-vapor ratio. Also, the method of comparing one tray layout with another, as illustrated by Table 9, shows that an optimum arrangement for efficiency and capacity can be selected; and furthermore, that this optimum is satisfactorily attained if the installed areas for caps and downcomers are made substantially equal to the respective required areas as established by the service conditions.

#### Other Types of Contact Devices

It is appropriate to consider some other devices that are used under various circumstances as alternatives to bubble caps, especially insofar as the relative advantages or disadvantages of bubble caps are illustrated thereby and insofar as capacity rating can be compared.

Perforated or sieve trays with downcomers, while having a record going back to the early days of the process industries, are also being even more widely used today, where their characteristics suit. For the same open area their dry-tray pressure drop is lower than that for bubble caps, as the number of velocity heads is only about half that of caps, that is,  $k$  of about 1.5 to 2.0 compared with 3 to 4 shown for riser and cap in Table 6. Hence, ordinarily a lower per cent open area could be advantageously used; say about 10% of the required cap area, compared with about 15% optimum for bubble caps. It is generally considered that sieve trays are not well adapted to low or to fluctuating rates, because of the possibility of losing the liquid; but if the liquid rate is quite high relative to the vapor, the sieve tray may offer the better opportunity of obtaining uniform dispersal and contact of the streams, with resulting improvement in tray efficiency.

In some degree similar to the sieve tray are the proprietary constructions which employ vanes and perforations (elements) to control dispersal of the liquid and to spread out the aerated phase not only over the area  $A$  above the elements, but also over the area  $C$  above the downcomers, so that the total area  $A + C$  becomes available for vapor disengaging. Then insofar as entrainment is the limitation to the capacity for a given tower size, a higher vapor rate is permissible, about in the ratio of  $(A + C)/A$ . It is thus possible to size the downcomer area  $S$  for a large liquid-handling capacity, and still retain a high capacity for vapor. Also, pressure drop may be lower, and dispersal of the liquid phase somewhat better than for bubble cap trays. The results are dependent upon the manufacturer's design for the particular service, but at least an interpretation in terms of the same factors as for bubble cap trays is possible.

In packed towers and slat towers the area available for vapor and liquid may approach the total cross section  $Y$  more or less closely. In the case of elements spaced so close as to suppress the formation of aerated phase, there would be a fundamental dissimilarity to bubble cap action. But if an open construction is used, with elements spaced evenly apart in layers, a closer similarity to the action of bubble caps or perforated trays might then result, yet with a difference in two respects. First, the vapor handling capacity could be made greater, about in the ratio of  $Y/A$  if the entire cross section is fully utilized. And second, a narrower range of good operability would typically be found, with results greatly dependent upon the size and spacing of the openings. This range of operability, as for bubble cap trays, is defined by the influence of the allowable flow rates of vapor and liquid each upon the other. Thus the total free area might be considered as subdivided into two areas,  $R$  and  $S$ , for passage of vapor and liquid respectively, so that as the proportionate area in the one service increases, that in the other decreases; the limitation (when not entrainment due to high superficial velocity) being pressure drop.

Thus, while the consideration of tray design has been specific only with respect to the use of bubble caps, it can also be seen that there are similarities between bubble caps and other types of contact devices which permit knowledge

in the one field being useful in the other also, especially for comparisons of performance data over a range of conditions.

#### Summary

In the design of bubble trays, it is necessary to proportion the cap areas and downcomers to the vapor and liquid loadings and to install caps with approximately the correct ratio of riser area in order that the tray may then operate at good efficiency and capacity. The required areas found by the design method are related by the interaction of vapor and liquid. A further consideration of this interaction relates it to the pressure drop. The numerical factors for sizing have been based upon the observations and calculations for about fifteen tests to ultimate capacity, for towers in a variety of services, embracing a wide range of operating conditions and a wide variety of bubble-tray apparatus.

It is recommended that in the sizing of equipment to be installed, the fullest consideration be given to all of the relevant circumstances known from experience and to each detail and dimension upon which the performance will ultimately depend. It is hoped that the present method will contribute to the soundness of commercial designs and to the satisfactory service of bubble-tray installations.

#### Acknowledgment

R. L. Dockendorff and T. Whelan were coworkers in the earlier work leading to the design method described here. The later development of the method has also been largely dependent on test data furnished by members of the technical staff of Humble Oil & Refining Co., to whom thanks are due.

#### Notation

- $a$  = required cap area, sq.ft.
- $b$  = required downcomer area, sq.ft. (inlet)
- $c$  = required downcomer area, sq.ft. (outlet)
- $f_a$  = factor for required cap area
- $f_b$  = factor for required downcomers
- $g$  = 32.2 (ft.)(sec.)(sec.)
- $h''$  = pressure drop/tray, in., of liquid
- $k$  = number of velocity heads,  $2g \cdot f/v^2$
- $l_1$  = required distance across cap area, ft.
- $l_2$  = required distance transverse to flow, ft.
- $q$  = vapor rate, cu.ft./sec.
- $s_1$  = specific gravity of liquid, relative to water
- $s_2$  = specific gravity of vapor, relative to water
- $u_0$  = allowable vapor velocity above cap region, ft./sec.



$u_r$  = vapor velocity inside risers, ft./sec.  
 $u_s$  = velocity of liquid in downpipes, ft./sec. = .00223 (gal./min.)/S  
 $w$  = vapor rate, lb./hr.  
 $y$  = required tower cross section, sq.ft.  
 $A$  = installed cap area, sq.ft.  
 $B$  = installed downcomer area, sq.ft. (inlet)  
 $C$  = installed downcomer area, sq.ft. (outlet)  
 $D$  = tower I.D. or tray O.D., ft.  
 $F$  = vapor friction, feet of fluid flowing  
 $F_{dp}$  = dry-plate pressure drop, in. of liquid on plate  
 $G$  = mass velocity, lb./sec./sq.ft.  
 $H$  = tray spacing, in.  
 $K_1$  = tray constant, for linear velocity  
 $K_2$  = tray constant, for mass velocity  
 $L_1$  = distance across installed cap area in direction of liquid flow, ft.  
 $L_2$  = distance across installed cap area transverse to liquid flow, ft.  
 $M$  = avg. mole wt. of vapor  
 $P$  = absolute pressure, lb./sq.in.  
 $R$  = total riser area, inside cross section, sq.ft.  
 $S$  = downpipe area, inside cross section, sq.ft.  
 $T$  = absolute temperature,  $460 + ^\circ F$ .  
 $V$  = unit gas volume, cu.ft./lb. mole  
 $X$  = edge losses around tray, sq.ft., 10 to 20% of  $Y$   
 $Y$  = total superficial cross section of tower, sq.ft. =  $A + B + C + X$   
 $Z$  = gas law correction factor,  $PV/10.72T$   
 $\rho_l$  = density of settled liquid, lb./cu.ft.  
 $\rho_v$  = density of vapor, lb./cu.ft.

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## ABSTRACTS

Abstracts of papers published in "Communications," Chemical Engineering Progress Symposium Series No. 8, Vol. 49 (1953), \$1 to members, \$1.50 to nonmembers. The volume may be ordered from Chemical Engineering Progress, 120 East 41 Street, New York 17, New York.

#### Semantics—Do You Mean What You Say?

Gilbert Brighthouse  
Occidental College

What men communicate—facts, purposes, feelings—the barriers raised in industry and social life against these communications, and the inadequacy of the media of communication are discussed informally. Good relationships between individuals are stressed as the keynote to successful communication.

*Chem. Eng. Progress Symposium Series, 49, No. 8, 1 (1953).*

#### Oral Communication

Dwayne Orton

International Business Machines Corporation

All the social devices of communication call to the attention of management the need for having within the industrial body the same psychological and social levels found outside it. Here is discussed one of the basic needs of management, the ability of the executive to identify himself with the interests, desires, point of view, and attitudes of the person with whom he is conferring.

*Chem. Eng. Progress Symposium Series, 49, No. 8, 7 (1953).*

#### Written Communication: When, What, and How

A. J. Johnson and Harold G. Vesper  
Shell Development Company

Too often technical and business writers forget that the success of their communication depends on how well it reaches and serves the reader. Outlined here is a method of handling incoming and outgoing mail in a sizable technical organization. Included are some hints on effective writing of reports and letters.

*Chem. Eng. Progress Symposium Series, 49, No. 8, 13 (1953).*

#### Objective Accounting: A Problem of Communication

Carl F. Braun  
C. F. Braun & Co.

Accounting is a method of communication often overlooked by engineers. Accountants' figures and reports are frequently presented to management with little consideration for engineering methods or for clear application to industrial methods. There is a need for a common language and application of engineering thought to accountants' reports on which management decisions are based.

*Chem. Eng. Progress Symposium Series, 49, No. 8, 21 (1953).*

#### A Solution to the Communications Problem

C. B. Barr  
Sinclair Research Laboratories, Inc.

Many organizations suffer from "too little

and too late" mail distribution systems. Here is described a system used in a research organization to provide wide distribution of incoming and outgoing correspondence and reports without sacrificing speed of delivery or central filing efficiency. Rapid copying of important incoming letters using Ozalid makes it possible for several men to read letters and reports immediately.

*Chem. Eng. Progress Symposium Series, 49, No. 8, 31 (1953).*

#### How to Organize Your Paper-Work Problem

Frank Knox  
Frank M. Knox Co., Inc.

Paper work is a production problem in the office. Forms constitute the raw material; clerical operations and procedures constitute the work in progress; and completed records comprise the finished goods. To organize paper work an inventory must be taken of all three factors, and a method must be evolved for correcting the problem and safeguarding against its recurrence. Simple, practical methods are presented for setting up and operating a control to reduce costs and speed up production of essential clerical operations.

*Chem. Eng. Progress Symposium Series, 49, No. 8, 37 (1953).*

#### Statistical Analysis of Experimental Data by Means of Punched Cards

C. E. Cummings and Jack Sherman  
The Texas Company Research Laboratories

Comparison of one set of data with another in order to determine significant differences generally requires statistical tests involving considerable computation, and communication of these data is often slow. In one company where these computations are carried out on punched-card machines the data are kept on cards from week to week so that semiannual and annual totals may be easily analyzed and long typed reports eliminated.

*Chem. Eng. Progress Symposium Series, 49, No. 8, 43 (1953).*

#### Electronic Data-Processing Machines

C. C. Hurd  
International Business Machines Corporation

This paper traces the history and development of digital computers and data-processing machines. The components which comprise the most modern electronic machines and the application of these machines to problems in scientific research, data reduction, and economic calculations are discussed.

*Chem. Eng. Progress Symposium Series, 49, No. 8, 49 (1953).*



# Vacuum Degasification in a Packed Column

## Deoxygenation of Water in Stedman Packing

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The packed column is useful in carrying out mass transfer between a gas and a liquid when the two fluids are passed countercurrent to each other. The purpose of this investigation was to establish the operating mechanism of a packed column operating as a cold-water vacuum deaerator, measure the transfer coefficient over the practical ranges of operating conditions, and compare its performance to that of a standard desorption tower.

Absorption theory has been based upon the concept of additive resistances, as has heat-transfer theory. In each case the total resistance to transfer is visualized as including the resistance of a stagnant film of each fluid of appropriate "effective thickness." The individual film-transfer resistances are added with any other resistances present to give the over-all resistance. The reciprocal is designated the over-all coefficient. The relation between the gas and liquid film resistances and the total resistance to mass transfer is expressed as follows (10):

$$\frac{1}{K_{Ga}} = \frac{1}{k_{Ga}} + \frac{1}{Hk_{La}} = \frac{1}{HK_{La}} \quad (1)$$

Chilton and Colburn (1) advanced an alternative concept in which the number of transfer units  $N.T.U.$  is used to measure the difficulty of the desired transfer, and the height of a transfer unit  $H.T.U.$  measures the effectiveness of the column packing (2). These different quantities are related as follows:

$$\frac{1}{(H.T.U.)_{OL}} = \frac{d(N.T.U.)_{OL}}{d(h)} = \frac{\ln[(x_i - x_e)/(x_o - x_e)]}{(h + h_{end})} = \frac{\rho K_{La}}{L} \quad (2)$$

where  $h$  is the actual height of the packing and  $h_{end}$  is the additional packing height that would produce the mass transfer that occurs in the inlet distributor and all other parts of the column except the packing.

Mr. Knoedler is now associated with Sheppard T. Powell, Baltimore, Md.

Contribution No. 36 from the Chemical Engineering Department, Engineering Center, Columbia University. For further details reference should be made to E. L. Knoedler, Ph.D. Dissertation (1952), Columbia University Library.

Vacuum desorption of oxygen from water has been studied in a 6-in.-diam. tower filled with 2 ft. of Stedman triangular packing. Packing heights were varied from 0 to 2 ft., water temperature from 52 to 112° F., liquid rate from 3,400 to 13,000 lb./hr. (sq. ft.), noncondensable gas pressure from 1 to 94 mm. and concentration of oxygen in the entering liquid from 3 to 12.7 p.p.m. by weight.

The liquid film offers the only resistance, and the corresponding mass-transfer coefficient was computed for each run. Below the loading point the data are correlated by the expressions:

$$H.T.U. = 0.078(L)^{0.8}$$

$$\frac{K_{La}}{D_L} = 200(L)^{0.77} \left( \frac{\mu}{\rho D_L} \right)^{0.53}$$

The film coefficients for the packing depend only on liquid flow rate, showing no variation with packing height, solute gas concentration, solute gas pressure, or temperature. End effects were found to be appreciable. When expressed as equivalent packing height they were a function primarily of temperature.

### Possible Mechanism of Vacuum-Deaerator Column Operation

Consideration of the factors in the operation of a vacuum deaerator indicates that some may be similar to those involved in an absorption column but others are completely different.

In an absorption column the inert gas flow rate  $G$  is substantially constant throughout the column and is large. In the case of the vacuum deaerator the only gas is that carried into the tower at the top dissolved in the liquid.  $G$  thus increases in going up the column and is negligibly small. The liquid stream is substantially constant in both cases. Neither type of column is operated flooded, and thus both may have a liquid-gas interfacial area per unit volume of packing that is constant throughout the packing.

The water temperature and, therefore, water-vapor partial pressure, remain substantially constant throughout a deaerating column because of the low water vaporization (an average of some 5 p.p.m. in this study). Thus an atmosphere of oxygen and water vapor substantially fixed in composition is maintained throughout the gas phase. Accordingly the gas film resistance is negligible and the liquid film coefficients may be calculated directly.

### Description of Apparatus

The general arrangement of the equipment for the deaeration studies is shown in Figure 1. The column was stainless-clad to prevent corrosion, and all other equipment in the system was

either coated with stainless steel or suitable paint or made of other corrosion-resistant material.

### DESORPTION TOWER AND PACKING

Deaeration was effected in the section labeled "Packed Deaeration Tower." It was constructed of nominal 6-in.-diam. pipe 2 ft. long between flange faces. Twenty-four inches of Stedman-triangular-pyramid type of packing completely filled the column. A flanged 4-in.-long pipe end connected to the bottom of the tower acted as a small reservoir for deaerated water.

### INLET LIQUID DISTRIBUTOR

A 6.25-in.-high distribution head section was mounted on top of the column. As shown in Figure 1, the inside of the top section included a redistributor plate located approximately 2 in. above the packing. The plate included seven removable orifices for controlling the liquid flow and four vapor risers which projected upward so that liquid water would not overflow through the risers. The orifices had an I.D. of 0.157 in. and were protected with a screen from plugging by solid particles.

### LIQUID RECIRCULATING SYSTEM

The deaerated water leaving the column flowed through a 2-in. Saran pipe to a centrifugal recirculating pump. This pump forced the water through two shell-and-tube heat exchangers connected to both a cold-water and a steam supply. The main stream of water flowed through a plug valve, a disk-type positive-displacement water meter calibrated at several temperatures, and a needle valve at the inlet of the deaeration tower to control the flow rate and to prevent oxygen evolution before the water entered the column.

GENERAL ARRANGEMENT OF EQUIPMENT FOR COLD WATER VACUUM DEAERATION  
(DESCRIPTION OF OXYGEN FROM WATER AT REDUCED PRESSURE)

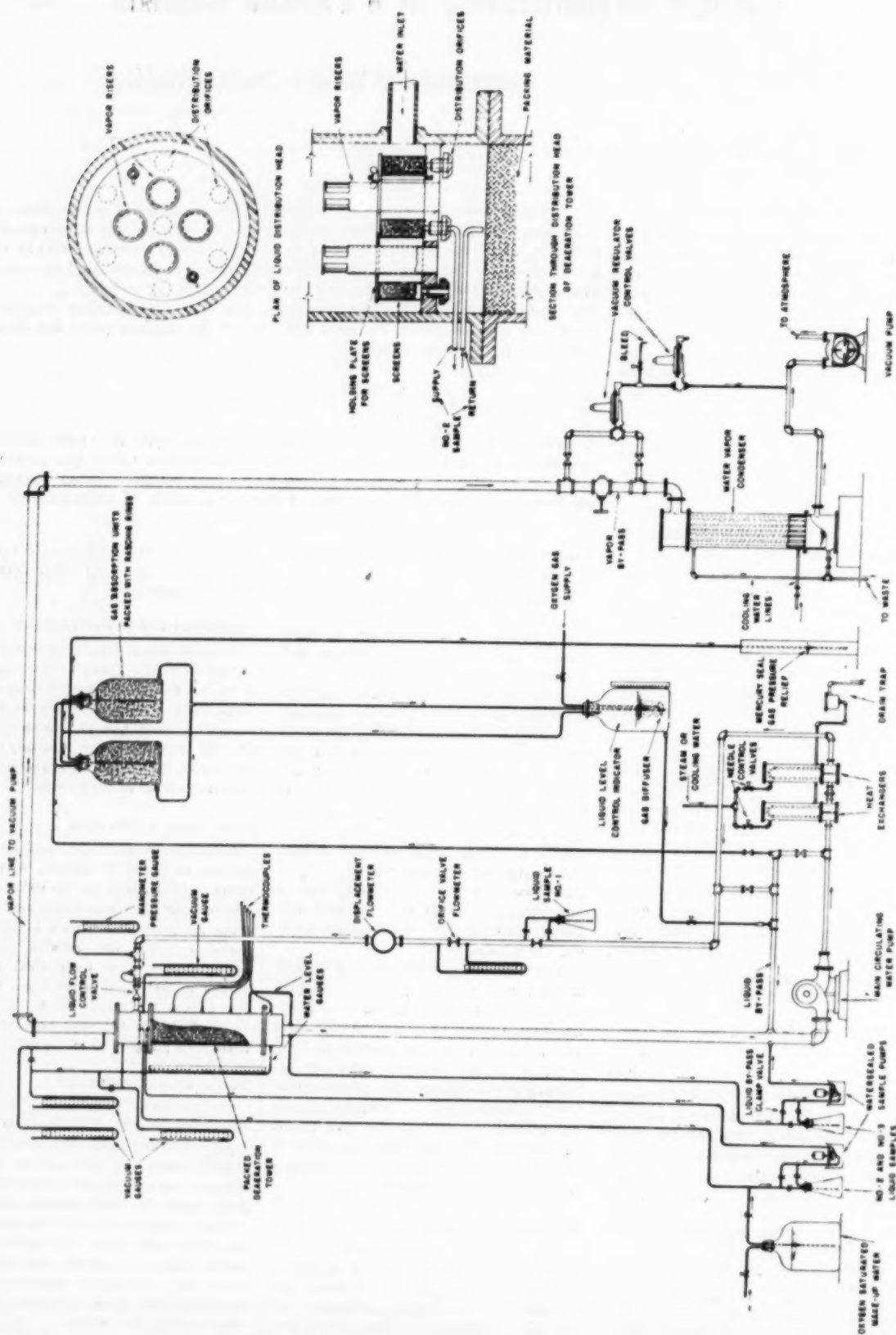


Fig. 1.

A U-tube mercury manometer was mounted across the plug valve to indicate the pressure drop. The valve was calibrated at several positions so that instantaneous liquid flow rates could be read directly. The integrated flow was read from the displacement water meter.

Water temperatures were measured at five locations by means of iron-constantan and chromel-alumel thermocouples and a potentiometer. The first point was located just before the needle valve at the entrance to the tower. The second, third, and fourth points were at 6-in. intervals deep in the packing. The final point was in the storage reservoir beneath the column. Differences among them were negligible. The deaeration tower was covered with 1 in. of magnesia and asbestos insulation.

#### GAS ABSORPTION SYSTEM

A side stream from the discharge of the main circulating pump was delivered to two 10-gal. glass gas-absorption bottles connected in parallel and packed with Raschig rings. Thence it flowed through an unpacked partially filled bottle which served as a reservoir for controlling the liquid level in the deaerator. The water returned from this bottle to the suction side of the main pump. Oxygen gas was bubbled through the unpacked bottle and then through the Raschig-ring-packed bottles, countercurrent to the water flow. Any excess flowed out of the system through a mercury seal.

The concentration of oxygen in the water delivered to the deaeration tower could be varied as described by suitably adjusting the flow of water in the side stream passing through the bottles.

#### GAS REMOVAL SYSTEM

A 2-in.-diam. steel line connected the top of the column to a condenser and a rotary oil-sealed vacuum pump. The vacuum was controlled by means of two spring-loaded diaphragm valves, the second connected so as to control the pressure on the diaphragm of the first.

The gauge pressure in the system was measured at four locations by mercury manometers in the vapor line, above the redistributor plate and just above and below the packing. The second and third locations always read the same, and the fourth also when the water level was below it and the full packing in use. The partial pressure of oxygen was computed by subtracting the vapor tension of water at test temperature from the observed total pressure.

To obtain satisfactory control of the pressure under the varying test conditions, it was found necessary to bleed a small amount of air into the vacuum piping system between the control valves. Thus gas removal rates could not be checked by direct measurement.

#### LIQUID SAMPLING

Water samples were obtained from three locations. No. 1 sample was collected by bypassing a valve in the main line feeding into the deaeration tower, No. 2 sample was collected below the central orifice of the redistributor plate, and No. 3 below the storage

Table 1.—Oxygen Desorption Data and Results

Test series	Packing height ft.	Inlet oxygen p.p.m.	Outlet oxygen p.p.m.	Packing N.T.U.
532-35	0.5	6.83	3.22	0.99
536-39	1.0	6.40	2.27	1.54
540-43	1.5	6.27	1.90	1.92
544-47	2.0	5.74	1.48	2.54
548-49	2.0	4.84	1.90	2.03
550-51	1.5	6.19	2.30	1.49
552-53	1.0	6.76	3.28	1.03
554-55	0.5	7.59	4.17	0.79
558-59	0.5	6.24	2.84	0.93
560-61	1.0	5.67	1.96	1.32
562-63	1.5	4.45	1.14	1.87
567-69	0.5	3.31	1.73	0.69
570-73	1.0	3.02	1.07	1.07
575-77	1.5	3.19	0.81	1.39
578-80	2.0	2.95	0.52	1.55
583-84	0.5	5.13	2.07	0.92
585-86	0.25	5.27	2.66	0.69
587-89	1.0	5.01	1.25	1.43
590-91	1.5	4.69	0.82	1.77
592-94	2.0	4.80	0.50	2.30
597-98	0.5	10.11	6.76	0.65
599-600	1.0	10.99	5.58	1.14
601-02	1.5	10.72	4.95	1.40
603-04	2.0	10.11	4.06	1.98
608-09	0.5	10.81	7.64	0.42
640-41	2.0	7.40	3.22	1.68
642	1.5	8.59	4.16	1.17
643-44	1.0	9.07	5.22	0.83
610-12	1.0	8.93	5.89	0.67
613-17	1.5	7.98	4.95	0.92
616	2.0	9.75	4.68	1.21
618	0.5	10.78	8.24	0.37
620-21	0.5	5.74	3.65	0.63
622-23	1.0	5.44	3.00	0.88
624-27	1.5	4.66	2.33	1.17
628-29	2.0	4.56	2.06	1.67
630-31	2.0	5.97	1.79	2.25
632	1.5	6.22	2.16	1.75
633-34	1.0	6.30	2.60	1.37
635	0.5	6.60	3.28	0.89
636	0.5	7.22	3.17	1.17
637	1.0	6.86	2.44	1.57
638	1.5	5.84	1.84	2.13
639	2.0	7.89	1.76	2.46
658	0.38	7.89	5.90	0.57
659	0.82	7.56	5.25	0.53
660	1.13	7.20	4.80	1.02
661	0.0	8.15	6.18	0.55
662	1.41	6.95	4.57	1.12
664	1.87	6.83	4.31	1.33
667	0.07	6.04	4.20	0.54
668	0.49	5.78	3.84	0.63
669	1.03	5.12	2.95	0.95
670	1.47	4.49	2.33	1.36
674	0.02	4.19	2.98	0.43
675	0.69	4.30	2.35	0.77
677	1.67	3.60	1.46	1.33
678	2.00	3.58	1.36	1.46
681	0.08	7.19	5.49	0.43
682	0.48	7.90	5.62	0.52
683	0.81	6.93	4.73	0.63

Table 1.—(Continued)

Test series	Packing height ft.	Inlet oxygen p.p.m.	Outlet oxygen p.p.m.	Packing N.T.U.
685	1.41	6.46	3.82	1.08
686	1.70	6.39	3.42	1.23
687	1.95	6.12	3.04	1.56
691	0.15	8.75	6.73	0.60
692	0.69	9.08	6.70	0.68
693	1.36	8.35	5.58	1.16
694	2.00	8.40	5.25	1.45
695	0.05	7.80	5.77	0.45
696	0.79	7.33	4.55	0.78
697	1.33	6.88	3.97	1.00
698	1.93	6.32	3.12	1.47
720	0.03	10.82	9.20	0.34
721	0.52	11.59	9.23	0.42
722	0.56	8.82	7.62	0.85
723	1.21	10.65	7.86	0.71
726	0.54	10.95	9.44	0.61
727	1.31	10.17	8.28	1.11
728	1.26	11.08	8.39	0.71
729	0.00	12.72	10.90	0.46
730	0.00	12.09	9.27	0.59
731	0.52	11.19	8.10	1.07
732	1.18	11.61	7.39	1.76
747	0.46	7.75	5.35	0.74
748	0.82	6.85	4.88	0.78
750	1.29	7.15	4.62	0.99
751	1.21	7.17	4.42	1.17
752	0.92	7.48	5.04	0.85
753	0.52	7.77	5.21	0.80
754	0.20	8.37	6.02	0.60
755	0.46	8.54	5.20	0.98
756	0.77	8.00	4.80	1.10
757	1.20	7.95	4.20	1.58
760	0.49	5.90	3.05	1.19
761	0.82	6.47	2.94	1.41
762	1.23	5.60	2.44	1.80
763	1.21	6.30	3.07	1.27
764	0.78	5.58	3.39	0.88
765	0.08	6.30	4.50	0.52
766	0.15	6.15	4.30	0.56
767	0.82	5.66	3.44	0.85
768	1.32	5.66	3.05	1.14
769	1.31	4.08	1.92	1.03
770	0.59	4.34	2.92	0.51
771	0.15	4.86	3.60	0.36
772	0.20	5.11	3.68	0.40
773	0.72	4.48	2.67	0.67
774	1.27	4.44	1.94	1.12
775	1.15	5.14	2.05	1.23
776	0.75	5.53	2.49	1.01
777	0.25	5.35	3.25	0.61
780	0.75	4.28	2.08	0.89
781	0.38	5.50	3.03	0.59
782	1.29	4.22	1.51	1.32
785	0.0	7.30	5.45	0.37
786	0.59	5.22	3.30	1.14
787	1.11	5.06	3.35	1.03
788	1.18	5.41	2.71	1.53
789	0.56	5.53	3.37	1.02
790	0.02	5.63	3.78	0.71

reservoir. Small centrifugal pumps were employed for faster circulation and collection of No. 2 and 3 samples. Each sample was removed by closing the valves to the bottle, opening the bypass around it, and disconnecting the bottle.

#### LEAKAGE

Since the system was under vacuum, air leakage was of constant concern. One of the principal sources was the pump bearings. The sample pumps were submerged in water to seal the pump glands. The bearing oil seals of the main circulation pump were made watertight by building up the sides with plastic wood and flooding them with water. The apparatus was always flushed with oxygen before any runs were started after an idle period, as well as when conditions were changed from one series of tests to another. During this flushing period the water was circulated through the equipment so as to stabilize all the water in the system under the new conditions.

Precautions to limit air admission also included painting all joints in the system with Glyptal varnish and bubbling pure oxygen through all make-up water before introduction into the circulating system.

#### Operating Procedure

It was necessary in the deaeration experiments to control and measure the following five independent variables: the concentration of oxygen in the water entering the tower, the total absolute pressure of the gas in the column, the temperature of the water in the column, the rate of flow of the water through the column, and the height of the useful (nonflooded) packing. In addition, the dependent variable of oxygen concentration in the water leaving the column was measured.

Many test series were carried out in which only the inlet oxygen content among the independent variables was modified between successive points. Other series were carried out in which only the effective packing height was varied by the expedient of operating at different liquid levels in the packing. In other successive series only the liquid flow rate or the vacuum was changed.

It was found difficult to hold other variables constant and fix the temperature at will because of the large effect of temperature on the vapor pressure of water and on the inlet and equilibrium concentrations of oxygen due to changes in gas solubility. Thus the effect of temperature was determined by carrying out several similar series of tests at any temperature levels obtained and the desired other conditions, and then interpolating to the desired temperatures.

#### MEASUREMENT OF OXYGEN CONCENTRATION

The dissolved oxygen in the liquid was determined by the Winkler method (12), which is suitable in the range involved. A modified procedure used as a check for interferences is similar to present A.S.T.M. methods (3,9). Blank tests showed that iron and other interfering substances were present only in negligible amounts in the water samples. The compositions



Table 1.—(Continued)

Test series	Temp. ° F.	Total pres. mm.	Oxygen pres. mm.	Water lb./ (hr.) (sq.ft.)	Oxygen equil. p.p.m.	End effect ft.	Packing H.T.U. ft.	Packing $K_{La}$
532-47	83.7	52.5	23.0	5,700	1.10	0.56	1.04	88.0
548-55	79.8	53.5	27.0	9,200	1.40	0.56	1.41	105.0
558-63	92.0	52.0	14.0	8,900	0.65	0.56	1.15	124.5
567-80	100.0	49.0	0.0	11,960	0.00	0.43	1.35	130.5
583-94	99.5	49.5	0.0	6,960	0.00	0.49	1.09	103.4
597-604	62.1	65.0	51.0	6,420	3.10	0.26	1.12	91.6
608-09	62.2	56.0	42.0	10,200	2.60	0.21	1.45	113.0
610-18	62.8	55.5	41.0	12,300	2.60	0.16	1.79	111.0
620-29	111.4	99.5	31.0	12,950	1.25	0.66	1.82	118.0
630-35	111.4	98.5	30.0	7,890	1.25	0.66	1.19	107.0
636-39	111.4	98.5	30.0	4,680	1.25	0.66	1.01	73.0
640-44	62.2	49.0	35.0	10,200	2.20	0.21	1.45	113.0
658-64	100.0	122.0	73.0	12,400	3.30	0.57	1.72	110.0
667-70	101.0	86.0	35.0	12,300	1.60	0.57	1.72	115.0
674-78	101.4	65.5	14.0	12,000	0.70	0.57	1.72	112.4
681-87	75.5	61.0	38.0	11,900	2.10	0.46	1.69	112.8
691-94	75.0	101.5	79.0	12,150	4.30	0.46	1.69	115.0
695-98	75.0	63.5	41.0	11,800	2.20	0.46	1.69	112.0
720-23	52.8	104.0	94.0	12,550	6.50	0.34	2.08	99.0
726-29	52.0	104.0	94.0	10,200	6.50	0.40	1.56	105.0
730-32	52.0	104.0	94.0	5,320	6.50	0.66	1.08	80.3
747-50	95.5	111.0	68.0	13,000	3.10	0.66	2.00	105.0
751-54	96.0	111.0	68.0	10,600	3.20	0.66	1.54	111.0
755-57	95.5	111.5	68.0	5,810	3.20	0.66	1.18	93.2
760-62	97.2	83.5	39.0	6,000	1.80	0.62	1.08	90.8
763-65	96.5	82.5	39.0	10,500	1.80	0.68	1.52	111.5
766-68	96.0	82.0	39.0	12,100	1.80	0.68	1.75	111.0
769-71	96.0	59.0	16.0	12,000	0.75	0.49	1.75	115.5
772-74	95.6	58.5	16.0	11,100	0.75	0.44	1.56	114.3
775-77	94.2	57.5	16.0	7,320	0.75	0.55	1.20	92.7
780-82	94.3	50.5	10.0	10,930	0.50	0.67	1.34	114.4
785-87	107.0	118.0	57.0	13,620	2.40	0.63	1.70	129.0
788-90	112.0	116.5	46.5	7,530	1.93	0.72	1.27	96.3

in Table 1 are of samples No. 2 and 3. The analysis of No. 1 was similar to that of No. 2 and was used infrequently as a check. No gas disengagement in sampling lines or bottles occurred. The analyses were reliable to within 0.04 p.p.m.

#### Discussion of Results

Many preliminary tests were carried out before the experimental technique was well developed and all leaks were corrected. Results are given in Table 1.

#### EQUILIBRIUM TESTS

In most series of runs an equilibrium test was included in which the side stream of water through the oxygen absorption bottles was shut off. In the equilibrium tests the dissolved oxygen content of the liquid samples should stabilize at the value corresponding to saturation at the temperature and oxygen partial pressure of the test. In Figure 2 are shown the Henry's Law constants obtained from the different test series and used in the interpretation of the results of this study. Included on the graph is an equilibrium curve based on literature data (5, 8). Agreement is

not perfect because of slight errors in measurements or analyses in the equilibrium tests.

Graphs similar to those in Figure 3 were prepared for all series. The straight line through the desorption test points in each series should intersect the 45° line at the concentration obtained in the equilibrium test. In most cases the agreement was close and indicated freedom from air leaks, as well as correct pressure readings and proper all-round operation of the column. If there was serious disagreement between Figure 2 and an equilibrium test or appreciable disagreement between the concentration in the water in the equilibrium test and the extrapolated concentration, as in Figure 3, the series of runs was discarded.

#### COMPUTATION OF H.T.U.

The slopes of the best straight lines of inlet vs. outlet concentration, as in Figure 3, were found for each group of runs for which all of the other conditions had been held constant. From Equation (2) the natural logarithm of each slope is the N.T.U. for the corresponding operating conditions.

The N.T.U. values were plotted against packing height, as in Figure 4, for each group of runs for which all other operating variables were constant. They were found to fall substantially on straight lines, indicating uniform liquid distribution and liquid-gas interfacial area. From Equation (2) the slope of each of these lines is the reciprocal of the H.T.U. of the packing alone for the corresponding operating conditions.

As in Figure 5, the H.T.U. increased with the water flow rate but there was no consistent trend with any other variable. Curved line *M* is drawn towards the higher (more conservative) points and should be suitable for design purposes. The curving suggests that an action comparable to loading may start at *L* = about 8,000 and similar to flooding at about 15,000. Straight line *M'* fits low flow rates and agrees in its slope with other liquid film data. Its equation is:

$$\text{H.T.U.} = 0.078(L)^{0.3} \quad (3)$$

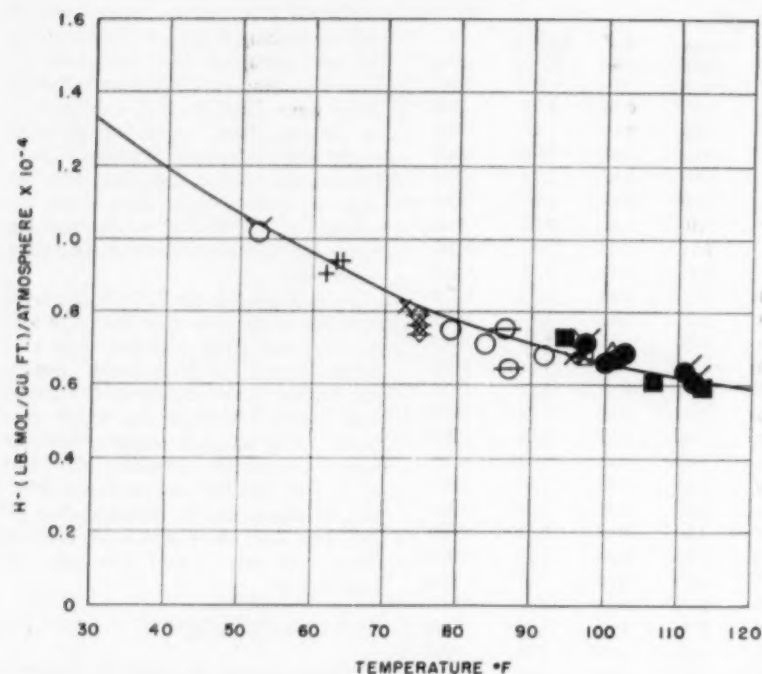
Extrapolating the lines of Figure 4 to zero N.T.U. gives the height of additional packing that would be equivalent to the end effect. These values, which have been included in Table 1, confirm the usual conclusion that end effects are appreciable for a short experimental column. The end effects were localized above the packing, since the runs with *h* = 2 ft. fall on the same straight lines in Figure 4, and they resided primarily in the drip below the distribution head, since No. 1 and 2 samples were quite similar in oxygen content. The end effect depended considerably on temperature and slightly on flow rate, but the reproducibility was poor. Within 0.2 ft., *h*<sub>end</sub> equaled 0.01(*t* - 32), for *t* in ° F.

#### Comparison of Results with Previous Studies

Even though the gas flow in these tests was substantially zero, as well as varying with packing height, some agreement would be expected with results of previous workers at low gas velocities under conditions such that liquid film resistance predominated. The principal results in the literature for this case are those for the stripping of oxygen from water by a stream of inert gas.

Close agreement could not be expected among the values of H.T.U. or *K<sub>L</sub>a*, because these quantities are affected by the nature of the packing. They also depend on the distributor system, the majority of previous workers not having corrected for end effects.

Sherwood and Holloway (11) inves-



### LEGEND

TEST	O <sub>2</sub> PRESS, MM	TEMP. °C.
○ 532-563	21	28.0
● 567-594	0	37.5
+ 597-618 + 640-44	42	17.0
● 620-639	30	44.0
● 658-678	14-73	38.5
◇ 681-698	38-79	24.0
○ 720-732	94	11.0
× 747-757	68	35.5
□ 760-768	39	35.5
△ 769-777	16	35.0
■ 780-790	38	40.0

Fig. 2. Solubility of oxygen in water. Comparison between literature (8) and equilibrium-test data.

tigated liquid film resistance in the desorption of oxygen, hydrogen, and carbon dioxide from water by a stream of air in Raschig rings and Berl saddles. Either there was no correction for end effects or they were compensated for only in part. Their results are also shown in Figure 5. Agreement is seen to be fairly good in spite of the considerable range in packing size and type.

Sherwood and Holloway correlated their results even better by plotting the ordinate of Figure 6 against  $(L/\mu)$ . This correlation, however, spread out the results of the present study, yielding a higher line the lower the temperature.

This suggested plotting merely against  $L$ . Figure 6 shows that the vacuum results correlate close to one curve and somewhat better than in Figure 5. The points at low  $L$  with no loading agree closely with Sherwood and Holloway's line  $A$  for a somewhat lower temperature range. The equation is:

$$\frac{K_{La}}{D_L} = 200(L)^{0.77} \left( \frac{\mu}{\rho D_L} \right)^{0.53} \quad (4)$$

Molstad and co-workers (6, 7) studied a large number of drip-point grid and some wood packings for stripping of various gases, using oxygen as a

standard for comparison with Sherwood's data. These studies also were made under conditions in which the liquid film resistance predominated, and end effects were not fully eliminated. Figure 5 shows that moderate agreement is obtained in spite of the rather high gas velocity. Vivian and Whitney (13, 15) used oxygen preliminary to experiments with chlorine and sulfur dioxide. Finally Deed, Schultz, and Drew (4) desorbed oxygen from air in a packed column at extremely low gas flow rates. As shown in Figure 5, fair agreement was obtained with Vivian and Whitney's data and good agreement with those of Deed, Schultz, and Drew.

The absorption by water of acetone vapor in air reported by White and Othmer (14) is the only previous absorption found on Stedman packing. Gas-film resistance was present, but their conclusion that the liquid-film coefficients are not much dependent on packing size is substantiated by Figure 5.

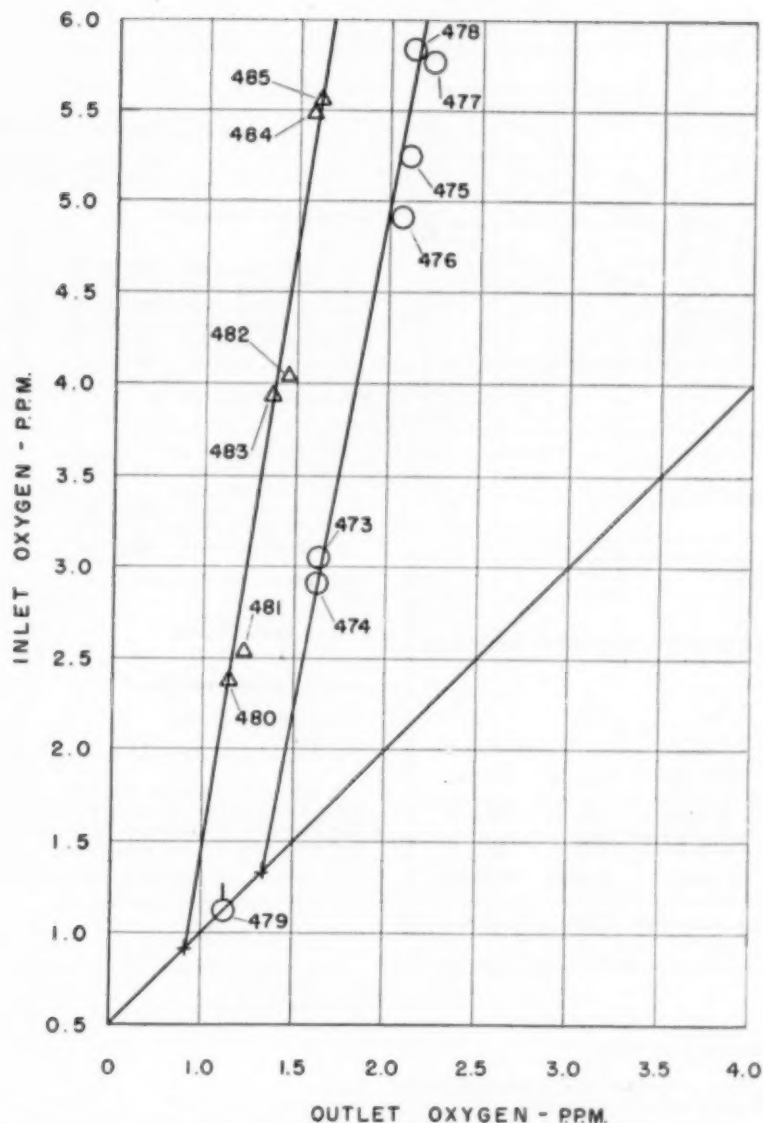
Moderately close agreement is thus obtained between vacuum desorption from Stedman packing and the above-mentioned liquid film controlled operations with rings, saddles, and large shapes. Although when tested on the same operations at low liquid flow rates Stedman packing has a smaller H.T.U. than the above-mentioned packings, it appears to flood at lower rates than do the coarser packings. It seems likely that rough design of vacuum degasification columns can be carried out by employing liquid film coefficients from absorption or desorption columns using somewhat similar packing and temperatures, low gas velocity, and the same liquid velocity.

### Acknowledgment

The cooperation of Mr. Martin Frisch and the Foster Wheeler Corporation, who supplied the packed tower, and of the Johns Hopkins University, which provided the laboratory space, is gratefully recognized.

### Notation

$d$	= differential operator
$D_L$	= coefficient of diffusion—solute gas in liquid, sq. ft./hr.
$G$	= inert gas flow rate, lb./(hr.) (sq. ft.)
$h$	= height of packing, ft.
$h_{end}$	= height of packing equivalent to end effects, ft.
$H$	= Henry's Law constant (lb. moles/cu. ft.)/atm.
$(H.T.U.)_{OL}$	= over-all height of transfer unit using liquid phase driving force, ft.



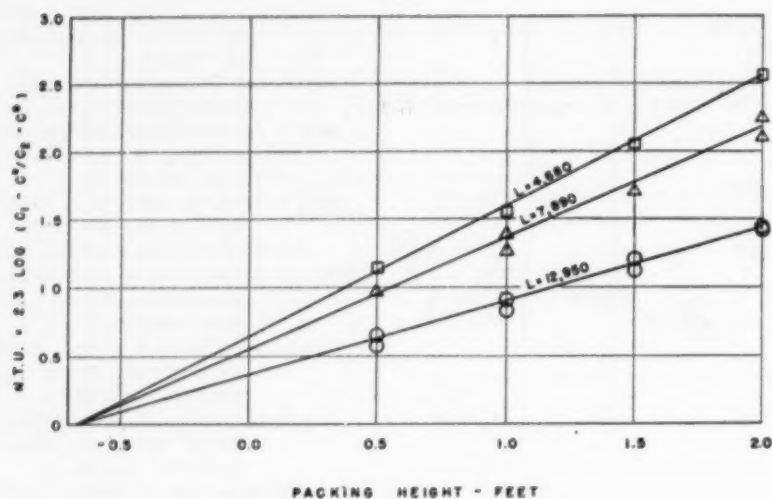
LEGEND		
TESTS	473-479	480-485
SYMBOL	○	△
TEMPERATURE °F	85.0	86.1
OXYGEN PRESSURE MM.	23.0	18.0
TOTAL PRESSURE MM.	54.0	50.0
FLOW - LBS/HR/SQ. FT.	6660	6480
EQUILIBRIUM TEST	○	
EQUILIBRIUM CALCULATED FROM PRESSURE	+	+

Fig. 3. Relation between concentration of oxygen entering and leaving packing.

- $(K_o a)$  = over-all coefficient based on partial pressure, lb. moles/(hr.) (cu. ft.) (atm.)  
 $(k_g a)$  = gas film coefficient, lb. moles/(hr.) (cu. ft.) (atm.)  
 $(K_L a)$  = over-all coefficient based on concentration, lb. moles/(hr.) (cu. ft.) (lb. moles/cu. ft.)  
 $(k_L a)$  = liquid film coefficient, lb. moles/(hr.) (cu. ft.) (lb. moles/cu. ft.)  
 $L$  = liquid flow rate, lb./hr. (sq. ft.)  
 $(N.T.U.)_{ot}$  = number of transfer units based on over-all driving force in liquid phase concentration units  
 $x_1$  = concentration of solute in liquid entering tower, lb. gas/(lb. water) (10<sup>3</sup>) (p.p.m.)  
 $x_2$  = concentration of solute in liquid leaving tower, lb. gas/(lb. water) (10<sup>3</sup>) (p.p.m.)  
 $x_s$  = concentration of solute in liquid in equilibrium with gas phase, lb. gas/(lb. water 10<sup>3</sup>) (p.p.m.)  
 $\mu$  = viscosity (lb.)/(hr.) (ft.)  
 $\rho$  = density, lb./cu. ft.

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LEGEND			
TESTS	620-629	630-635	636-639
SYMBOL	○	△	□
TEMPERATURE °F.	112.0	111.4	111.4
OXYGEN PRESSURE MM.	31.0	30.0	30.0
TOTAL PRESSURE MM.	99.5	98.5	98.5
LIQUID FLOW-LBS/HR/SQ. FT.	12,950	7,890	4,680

Fig. 4. Relation between number of transfer units and packing height at different liquid flow rates.

## APPENDIX

### Problem—Application of Data to Design of Vacuum Distillers

As an example of the procedure, find the depth of Stedman packing required for the following design conditions. Assume the same end effects as found in this study.

#### DESIGN CONDITIONS

Temperature	= 83° F.
Flow—g.p.m./sq.ft. = 25; lb./hr.(sq.ft.)	= 12,500
Vacuum specified—28.7 in. Hg	= 31.0 mm.abs.pres.
Conc. of oxygen in liquid—	
Influent	$x_1$ = 8.00 p.p.m.
Specified effluent	$x_2$ = 0.25 p.p.m.
Equilibrium with gas phase	$x_2$ (from Fig. 2) = 0.10 p.p.m.

Formula:

$$[1/(H.T.U.)_{OL}] = \frac{2.3 \log [(x_1 - x_2)/(x_0 - x_2)]}{h + h_{(end)}}$$

#### CALCULATIONS

$(x_1 - x_2)/(x_0 - x_2)$	= 52.7
$2.3 \log [(x_1 - x_2)/(x_0 - x_2)] = (N.T.U.)_{OL}$	= 4.0
$(H.T.U.)_{OL}$	= 1.8 ft. (from Fig. 5)
$h_{(end)} = (83 - 32)/100$	= 0.5 ft.
$h + h_{(end)} = (N.T.U.)_{OL}(H.T.U.)_{OL} = 4 \times 1.8$	= 7.2 ft.
Necessary packing depth = $h = 7.2 - 0.5$	= 6.7 ft.

(From experience it may be stated that this is a reasonable size of column for the job outlined.)

#### Legend for Fig. 5.

Gas Flow Temp. Packing  
° C. Hgt.-in.

#### Sherwood and Holloway (11)

in.			
A—0.5 Raschig rings.	100	20-22	13
B—1.0 Raschig rings.	100	19-25	17-49
C—1.5 Raschig rings.	230	23-25	19
D—2.0 Raschig rings.	230	23-25	20.5
E—0.5 Berl saddles.	100	23-26	15
F—1.0 Berl saddles.	230	23-26	17

#### Vivian and Whitney (13, 15)

in.			
G—1 tile Raschig rings (4-in. diam. tower)...	120	21	24
H—1 tile Raschig rings (14-in. diam. tower)...	60	21	96
I—1 tile ceramic rings (8-in. diam. tower)...	355	21	24

#### Deed, Schultz and Drew (14)

in.			
J—0.5 ceramic Raschig ring .....	Low	25	47

#### Malstad, McKinney and Abbey\* (7)

K—No. 6295 drip point grid** .....	570	27
L—3-in. partition tile**	570	27

K and L cover upper and lower limits of test data. Other packings include 6897 and 6146 drip point grid, 3-in. single and triple spiral tile, and wood grids with and without legs.

\* H.T.U. values corrected to 25° C.

\*\* Continuous flow arrangement.

#### Knoedler and Bonilla

M—Stedman triangular packing Legend—(See Fig- ure 2) .....	0	11-44	6-24
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#### Legend for Fig. 6.

Gas Flow Temp. ° F.

#### Sherwood and Holloway (11)

A—1.0-in. Raschig rings	100	41.0
B—1.0-in. Raschig rings	100	95.0

#### Knoedler and Bonilla

C—Stedman Triangular Packing (See Figure 2 for legend)	Nil	52-111.4
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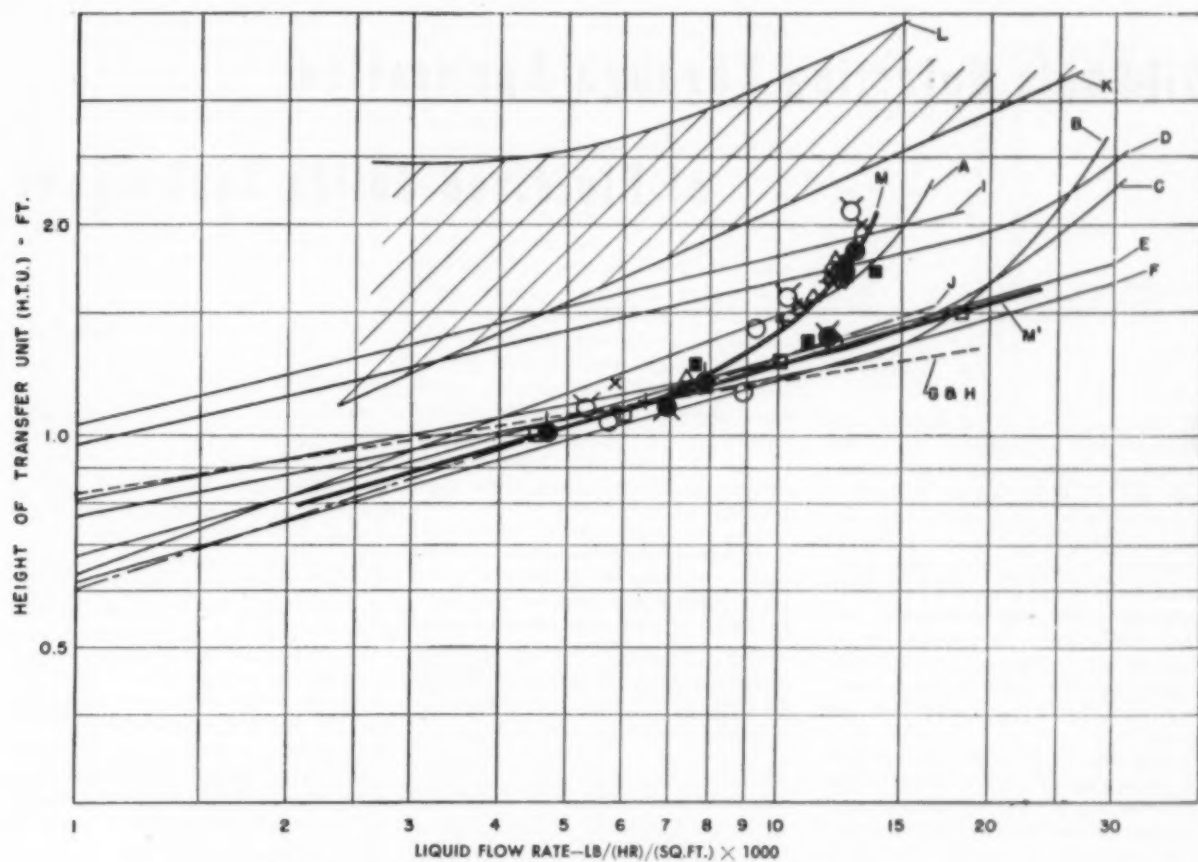


Fig. 5. Comparison of test data with oxygen desorption results of other investigators.

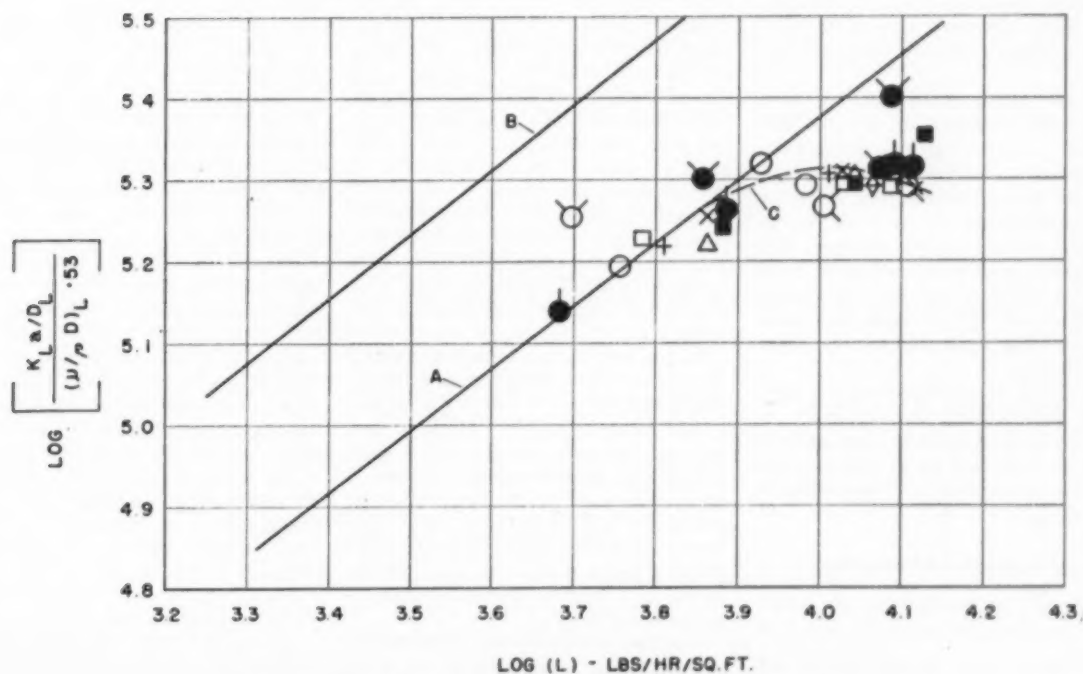


Fig. 6. Comparison of test data with results of Sherwood and Holloway (11).

# Oil-Shale Retorting Through Application of Fluidized-Solids Techniques

H. F. Wigton and B. E. Lauer      University of Colorado, Boulder, Colorado

**A** single deposit of oil shale located in western Colorado contains almost three hundred billion barrels of recoverable oil (1) and (14), an amount reported to be equal to several times the estimated reserve of liquid petroleum in the entire world (2). In spite of this huge, concentrated store of raw material with relatively easy accessibility and low mining cost, no process yet developed has attracted private capital for a plant to produce oil in free competition with liquid petroleum from the ground.

Basically, the technical problem of producing oil from shale is that of separating a relatively small quantity of organic material from a fairly large body of inorganic residue. The problem is complicated by the fact that the organic (kerogen) material in the shale is a solid almost insoluble in most ordinary solvents (3). However, by thermal action, retorting, the kerogen is partially converted to gaseous and liquid organic materials removable as vapor.

To retort shale successfully has been a perennial challenge to the chemical engineer. In the retorts which have been developed for the purpose, the high price of the equipment, the excessive heat requirements, the poor yields, the semisolid nature of the products, and the general mechanical difficulties have all conspired to make the operation a gamble in which the stakes have been fantastic but the returns, to date, disappointing.

By using the fluidized-solids techniques and securing, through their use, the high heat-transfer rates peculiar to them, an improved retort has been designed and operated for the production of shale oil.

## The Current Practices of Retorting

Although many designs of retorts have been built to use cross flow, belt

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conveyors, tunnel heaters, and various other mechanical patterns of operation (4) to (7), only four fundamentally different types of retorts have been proposed:

1. Gas-producer types
2. Gas- or vapor-heated types
3. Solids-recycle types
4. Closed or coke-oven types

In a gas-producer type of unit, hot combustion gases are formed within the retort by burning some of the organic material or carbonaceous residues, or both, with air. The hot combustion products, passed into the raw shale, heat it by direct contact, (8, 6, 1). One significant disadvantage of this type of retort is that combustion products and recycle gases so dilute the oil-shale vapors that the product is difficult to recover. The recovery of valuable light ends becomes uneconomical and any direct vapor-phase treatment of the shale-oil vapors is precluded. Further, since free circulation of gas is necessary for the operation of this retort, the size of particles of shale which can be treated must be greater than about  $\frac{3}{8}$  in. The long time required to heat a coarse lump of shale to its center results in low capacity, low thermal efficiency, incomplete retorting, and uncontrolled cracking of the evolved shale vapors. The recovered product is likely to be a highly viscous oil, while the light ends are lost by overcracking, burning, and venting.

In the gas- or vapor-heated type of retort, the shale, held in a fixed or slowly moving bed, is retorted by superheated steam or hot recycle gas heated in an external furnace (10, 7). Except for product dilution, which is much minimized by the substitution of steam for noncondensable gases, this retort has general limitations similar to those of the gas-producer type of retort; steam as a heating medium introduces additional difficulties.

The heat supply in the solids-recycle type of retort is delivered by recycling hot, burned, spent shale into the retort,

approximately 10 lb. of recycle solid being required to retort 1 lb. of raw shale. Hot shale is mixed with raw shale in a fluidized bed. In this retort the necessity for recycling large quantities of solids multiplies the problems of stripping residual gases from the solids, lowers the yields, increases the difficulty of control, and imposes serious mechanical problems.

The coke-oven type of retort is characterized by heat transfer through the retaining walls, although it may have part of the heat introduced as steam directly into the shale mass (5, 8). The closed retort, which can handle either lump or ground shale, eliminates several of the disadvantages of the gas-producer type, notably the difficulties caused by dilution of the product.

When lump shale is retorted in a fixed bed, the low rate of heat transfer to beds of broken solids results in low capacities for the unit and high capital outlay per unit of capacity. Substitution of a moving bed causes mechanical complications—feeding and discharging a lump solid without breaking the gas seals. In either case the temperature required to drive heat through the wall and then into a massive solid is excessive; thus the possibility of using metal retaining walls for the retort is eliminated.

The use of fine particles in a closed retort should give the same general advantages of coarser ones in the same type of equipment, that is, an oil of a vastly superior quality, gas of high enough heating value to be commercially useful, by-products recovery, and other advantages due to elimination of inert gases for heating.

There are two techniques for using the closed retort to treat ground shale—one in which the bed is either fixed or settles slowly through the retort, the other in which the bed moves rapidly enough to create internal circulation of particles, fluidized bed.

In a closed retort the fixed or slowly moving bed of finely divided solids has disadvantages similar to those of a

fixed bed of lumps. These are due to the extremely low rate of heat transfer to a fixed bed of any thickness and the resulting necessity for high wall temperatures. The fluidized bed in a closed retort has all the advantages of the closed-retort treatment and also, because of the excellent heat-transfer rates to a fluidized solid (11, 12, 13), has large capacities without excessively high wall temperatures. Hence metal retaining walls are feasible.

#### THE PROBLEM

A number of patents cover various phases of retorting oil shale in a fluidized bed (15), but the authors do not know of any published details of the construction or operation of a retort combining in a single unit a fluidized bed for retorting shale, internal combustion of retorted shale, and heat transfer through a metallic wall separating the two zones. A practicable retort having these features was constructed and operated continuously for the production of shale oil.

#### Apparatus

The retort required the following parts: feed device, including a method of controlling the rate of feed as well as of introducing feed to the reactor; a raw-shale preheater; a shale retort; a vapor-solids separator; and a combustion section in which heat could be generated for retorting.

By experimentation the retort shown in Figures 1, 2, and 3 was developed. It is designed to permit shale to enter near the bottom, flow progressively upward through three preheating zones, pass through an annular retorting zone, and overflow into a stripping zone, which serves as a standpipe to feed the combustion zone. The bed level of solids in the combustion zone is automatically controlled by the combustion-zone overflow lines, through which all the products of combustion are fed out of the retort.

A stepwise flow of solids upward through the preheating zone is effected through a series of constrictions in the cross-sectional area normal to the upward flow, the velocity of gases through such a constriction being sufficient to transport the particles upward. The solid particles entering the lowest fluidized preheating zone physically displace some of the solids already present in the zone so that these solids are transported upward through the constricted area and into the next zone. In this manner the advantages of both dense-phase fluidization (high heat-transfer coefficients) and countercurrent operation (high thermal efficiencies and high driving-temperature differences) are obtained.

The retorting zone is the annular space between a 3-in. O.D. tube and 3½-in. I.D. tube, the combustion zone is inside the 3-in. tube, and the stripping section is a 6-in. length of

1½-in. O.D. tubing. The combustion-solids feed valve, which is located within the stripping zone, is ¼-in. pipe welded shut at the end and sealed by grinding into an open section of ¼-in. pipe.

The combustion-products discharge tubes consist of six ¾-in. tubes 11 in. long, closed at the top, each with four 3/16-in. holes drilled in the side near the top to maintain automatically the bed level of solids. These discharge lines pass through a metal plate ¼-in. thick which forms the bottom of the combustion zone. From the bottom of this separating plate these tubes extend downward and comprise the heat exchanger of the shale-preheating unit. The combustion air enters the system through a ½-in. O.D. tube which passes upward centrally through the preheating section and enters the bottom of the combustion zone.

The combustion-zone thermocouple well serves as an inlet tube through which the combustion zone can be initially charged. A manometer connected to this line indicates the pressure in the top of the combustion zone.

The shale enters the retort through a valve constructed of ½-in. pipe in such a way that an opening in the horizontal pipe will exactly fit a vertical pipe only at one position. The opening can be varied by turning the horizontal line. The feed standpipe is a 5-ft. length of 3-in. drainpipe.

A vapor-offtake line of ¼-in. pipe leads horizontally from the stripping zone into a vertical air condenser which consists of a 3-ft. section of 2-in. O.D. 18-gauge steel tubing joined to the first water condenser, which discharges into a 1-in. diam. cyclone. Light ends are collected in a series of four water-cooled condensers which follow the recycle-gas blower.

Measurements of gas flow, temperature, and electrical power input were made respectively with Fischer and Porter flowmeters, a Leeds and Northrup multipoint recorder, and a Weston Model 531 AC wattmeter.

The dimensions of the several sections and their areas are as follows:

	sq. ft.
Preheating section: 1½-in. O.D.; 15½-in. long	
Superficial inside area .....	0.015
Free cross-sectional area .....	0.01
Cross section of baffle opening .....	0.0006
Heat-transfer surface of tube bundle (inside area of six ¾-in. tubes; 15½ in. long) .....	0.58
Retorting zone: Annular space between 3-in. O.D. and 3½-in. I.D. tube; length 20 in.; volume 0.0296 cu.ft.	
Superficial cross-sectional area .....	0.018
Area through which heat is transferred from the combustion zone (8-in. length of 3-in. tubing plus 3-in. disk) .....	0.70
Stripping section: 1½-in. O.D.; 6 in. long (less cones)	
Superficial cross-sectional area .....	0.0134
Combustion zone: 3-in. O.D. tubing; 20 in. long	
Superficial cross-sectional area .....	0.045
Free cross-sectional area .....	0.04
Area through which heat is transferred to retorting zone (8-in. length of 3-in. tubing plus disk 3-in. I.D.) .....	0.70
Combustion products cooling: Bundle of six ¾-in. tubes, 15½ in. long.	
Disengaging section: 6-in. I.D., 8 in. long.	

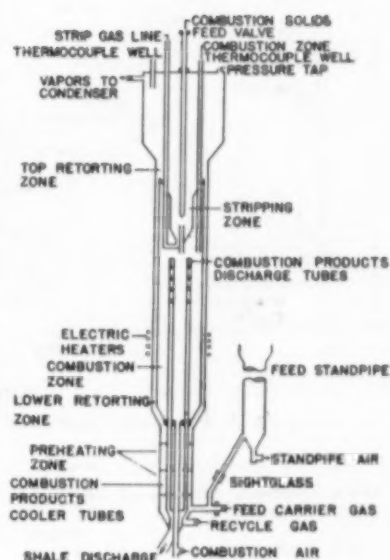


Fig. 1. Details of oil-shale-retort construction.

#### SHALE SAMPLES

Oil shales from the Colorado deposit vary widely in organic content and character. Only shale from the minable-bed deposit which is currently being worked by the U. S. Bureau of Mines Demonstration at Rifle, Colorado, was investigated. This deposit averages 30 gal. of oil yield/ton of shale.

The oil shale was ground in a 1- by 2-ft. rod mill containing a charge of 300 lb. of ¾- to 1¼-in. diam. steel rods. The size range of the sample used is shown in Table 1.

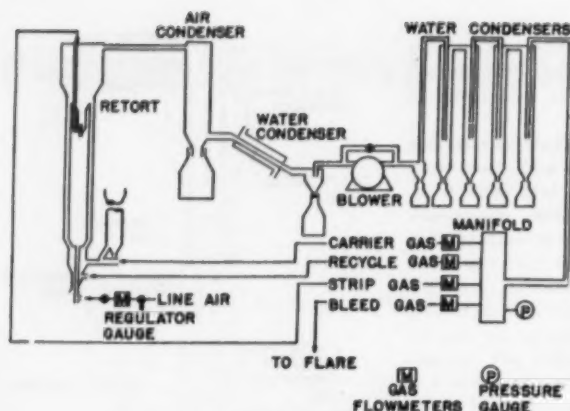


Fig. 2. Flow chart—oil-shale-retorting system.

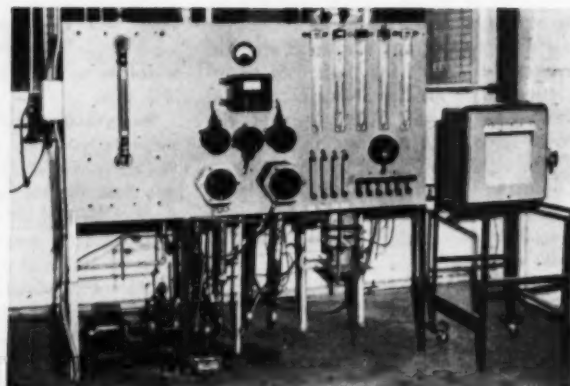


Fig. 3. Control panel for oil-shale retort.

Table 1.—Screen Analysis of Oil Shale

Tyler mesh size	Weight per cent retained
+ 35	7.8
— 35 + 48	37.1
— 48 + 65	27.1
— 65 + 100	15.7
— 100 + 150	8.0
— 150 + 200	3.1
— 200	1.2
	100.0

#### PROCEDURE

The top of the retort was opened to the atmosphere, and recycle-gas, stripping-gas, and purge-gas lines were opened. The solids valve in the stripping section, which controls the solids flow in the combustion zone, was closed during the start-up period. The recycle blower was started and the manifold pressure adjusted. Raw shale was charged into the unit via the initial-feed mechanism until the stripping section was filled, depth of solid being indicated by the manometer reading. Electrical heat was then applied to the unit and the top of the retort was connected to the condensing system. The heater was then adjusted to maintain the average retorting temperature in the retorting zone, thus compensating for heat loss through the outside walls of the retort. Except for the electrical heater, the unit was then shut down.

The condenser bottles were changed and the standpipe was drained and refilled with shale from the weighed sample. The blower was started and raw shale was fed slowly into the unit. The solids-feed valve controlling delivery to the combustion zone was opened and the combustion air set at a nominally low value. As soon as the overflow of solids from the combustion zone became visible at the solids-discharge line, the feed rate and combustion air were increased. After initial regulation the combustion-air and solids-feed rates were held constant through each run.

The run was terminated by closing both the

(Run at 970° F.)

Total shale processed	20 lb.
Total operating time	1.0 hr.
Total organic material	3.9 lb.
Total available oil (by Fischer assay)	2.4 lb.
Total oil collected	2.3 lb.
Yield	96% of Fischer assay
Total water	0.1 lb.
Total air	65 cu.ft.
Total discharged shale	16 lb.
Heat to retorting zone	4,100 B.t.u.
Electrical heat to retorting zone	Not calculated
Heat to preheating section	2,860 B.t.u.
Retorting rate	1,100 lb. shale/hr.sq.ft. of cross-section
Combustion rate	500 lb. raw shale/hr.sq.ft. of cross-section
Over-all rate	300 lb. raw shale/hr.sq.ft. of cross-section
Heat transfer requirements:	

$$\frac{1.28 \times 2000}{20 \times 24} = 5.4 \text{ sq.ft. days/ton of shale}$$

#### Heat transfer coefficients

Combustion zone to retort zone	32 B.t.u./hr.sq.ft.° F.
Preheat zone	11 B.t.u./hr.sq.ft.° F.

Table 3.

Run at 920° F.

Total shale processed	51.5 lb.
Total operating time	2.6 hr.
Total organic material	9.8 lb.
Total available oil (by Fischer assay)	6.2 lb.
Total oil collected	6.3 lb.
Yield	0.3 lb.
Total water collected	101% of Fischer assay
Total air	118 cu. ft.
Total discharged shale	41 lb.
Heat to retorting zone from combustion zone	7,400 B.t.u.
Electrical heat to retorting zone	2,600 B.t.u.
Heat to preheating zone	6,750 B.t.u.
	16,750

Retorting rate	1,100 lb. shale/hr.sq.ft. of cross-section
Combustion rate	500 lb. raw shale/hr.sq.ft. of cross-section
Over-all rate	300 lb. raw shale/hr.sq.ft. of cross-section
Heat transfer requirements:	

$$\frac{1.28 \times 2000}{20 \times 24} = 5.4 \text{ sq.ft. days/ton of shale}$$

#### Heat transfer coefficients:

Combustion zone to retort zone	24 B.t.u./hr.sq.ft.° F.
Preheat zone	10 B.t.u./hr.sq.ft.° F.



**Table 4.—Shale-Oil Distillation**  
Crude Shale Oil Retorted at 970° F.

I.B.P.	Topping			Redistillation	
	vapor	liquid		vapor	liquid
	175° F.	270° F.			
%			%		
5	320	405	5	180° F	235° F
10	355	440	10	285	320
15	385	475	20	335	360
20	415	515	30	360	380
30	490	600	40	385	410
36 E.P.	520	640	50	410	430
			60	430	450
			70	460	475
			80	500	510
			90	550	565
			95		

Viscosity 92 Saybolt Universal Seconds at 100° F.  
Viscosity 170 Saybolt Universal Seconds at 70° F.

3 ml. residue, 2 ml. loss

**Table 5.—Shale-Oil Distillation**  
Crude Shale Oil Retorted at 970° F.

I.B.P.	Topping			Redistillation	
	Vapor	Vapor		Vapor	Vapor
	210° F.	198° F.			
%			%		
2.5	250	10	267		
7.5	310	20	302		
10	318	30	332		
15	350	40	356		
20	372	50	375		
25	408	60	388		
30	438	68	400		
35	464	71	410		
40	490	80	445		
45	508	90	470		
		95	484		
50	520	99 E.P.	530		

Viscosity 50 Saybolt Universal Seconds at 150° F.  
Viscosity 170 Saybolt Universal Seconds at 70° F.

1 ml. residue, no loss

valve to the combustion zone and the one feeding the retort. The bleed-gas and by-pass valves were opened simultaneously. The blower was stopped when the manifold pressure reached 1 or 2 lb./sq.in. The electrical heater was then turned off. After the unit had cooled, the combustion zone was emptied of solids, and the stripping section was drained into a sample container. The oil which had been collected was weighed and all of it except the light ends was redistilled.

#### PERFORMANCE

The performance of this unit is shown in Tables 2 and 3. The properties of the oils produced are shown in Tables 4 and 5. Material and energy balances are given in Figure 4.

Thus, in a laboratory-scale retort for oil shale, both retorting and combustion have been simultaneously conducted in separate fluidized beds, and there has been no admixture of combustion gases with the vapor products nor of spent shale with fresh shale.

High yields of a low-viscosity oil, high thermal efficiencies, high heat-transfer coefficients, short residence time and phenomenal throughput of shale per unit cross section, good combustion of the residual carbon in the shale, excellent control, no char formation on the heating surfaces, and smooth continuous operation were all characteristic of this retort.

The several fundamentally important advantages of this method follow:

1. The residence time and temperature can be varied at will, and hence the

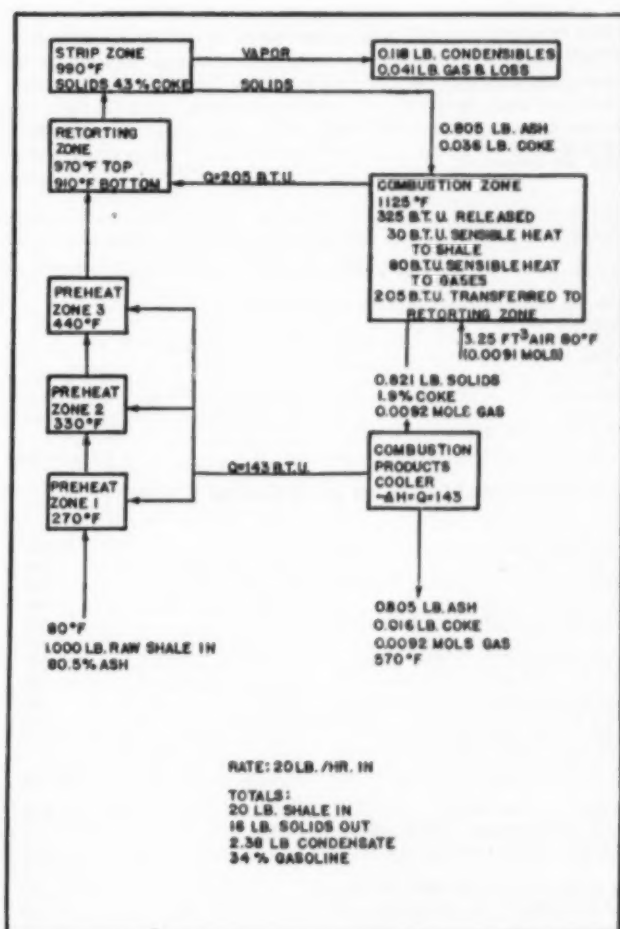


Fig. 4. Material and energy balance of oil-shale retort operated at 970° F.

history of the oil shale can be kept under control at all times. This feature has not been duplicated in any other process.

2. The recycle gas requirements for fluidization are very low, and this recycle gas is not subjected to excessively high temperatures; hence, without dilution of the gases or vapors, the recovery of valuable light ends can be virtually complete.
3. Because of the excellent heat-transfer rate to a fluidized bed the capacities can be made large without high wall temperatures. Lower wall temperatures permit the use of light-gauge steel for construction, give lower thermal losses by radiation or convection, and keep the temperature below the decomposition temperatures for carbonates. Hence thermal losses through that channel are minimized.

4. The shale, being finely divided, can be easily divested of the bulk of its carbonaceous residue in the production of heat. Combustion is rapid at temperatures as low as 900° F.

This type of retort does require that the shale be ground, but grinding costs are not prohibitive.

#### ESTIMATED COMMERCIAL COSTS

By extrapolating the actual performance data of this laboratory unit and using recently published equipment costs and estimating factors (16) and (17), the following costs for a commercial retorting plant handling 20,000 tons/day of shale are obtained.

All the cost data have been corrected to an *Engineering News Record* index of 550, which is approximately the current value.

Heat-transfer surface $5.4 \times 20,000 = 108,000$ sq.ft.		
Cost of steel heat exchanger with stainless steel tubes	\$7/sq.ft.	
Installed reactor cost		\$760,000
Compressor requirements: 90,000 cu.ft./min. air		
20,000 cu.ft./min. recycle		
Cost of turbo blower handling 45,000 cfm at 6#	\$70,000	
Installed air compressor		\$ 140,000
Installed gas blower		30,000
		-----
Total equipment installed		930,000
Plant costs (using mult. factor of 2.55)		\$2,370,000
Condensing System: Figured as crude topping plant		\$ 550,000
Contingency		580,000
TOTAL INVESTMENT		
Retorting	\$3.5 million	
Grinding	2.6 million †	
Mining	4.5 million *	
		-----
		\$10.6 million
An estimate of retorting costs based on one day of operation follows		
Depreciation		
Main reactor (1 yr.)	\$2,080	
Rest of plant (10 yr.)	750	
Operating labor	600	
Maintenance labor	600	
Salaried personnel	200	
Overhead	400	
Utilities	800	
Taxes	100	
Insurance	150	
Interest at 3½%	350	
Contingencies	400	
		-----
		\$6,430
Cost of retorting 1 ton of shale	\$ 0.32	
Cost of mining and crushing 1 ton of shale	0.40 *	
Cost of grinding 1 ton of shale	0.30 †	
		-----
Total cost of processing 1 ton of shale (30 gal. oil)	\$ 1.02	
Total cost of producing 1 bbl. of oil (42 gal.)	\$ 1.43	

\* Bureau of Mines estimate.

† Estimate of Marcy Mill Division of Mine & Smelter Supply Company.

#### Conclusion

Finely ground oil shale can be completely retorted in a fluidized bed at rapid rates under controlled conditions, with both the raw and retorted shale remaining particulate and free flowing at all points in the process. Shale retorted under these conditions contains more than enough carbonaceous residue in an available form to supply the fuel requirements for the entire process, and the combustion of this carbonaceous residue in a fluidized bed is extremely rapid.

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# Continuous Countercurrent Ion Exchange with Trace Components

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Ion-exchange separations are normally conducted batchwise by saturating and eluting a fixed bed of resin. This process has the usual disadvantages of a cyclic operation, producing variable effluent concentrations as well as being complex and time consuming. In an attempt to eliminate the shortcomings of the cyclic process, Stanford Research Institute has undertaken an investigation of continuous ion separation by means of countercurrent contact between resin and solution.

## Fundamental Theory

### GENERAL

The separation of ions by ion exchange operates by the transfer of ions between a solid-resin and a fluid-solution phase. The differences in affinities of the resin for the ions to be separated, say ions  $A$  and  $B$ , lead to an enrichment of the less strongly held, say  $A$ , in the fluid phase and of the other,  $B$ , in the solid phase. In countercurrent operation the phases move in opposing

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A design theory based on kinetic and equilibrium considerations was developed for countercurrent ion exchange under trace conditions. Equipment was designed to provide continuous countercurrent contact between a moving bed of ion-exchange resin and the solution to be treated and was evaluated experimentally by the separation of trace ionic components in a feed solution. Contact efficiency at low flow rates was improved with a vibrated-screen assembly which was immersed in the moving bed and which produced continual reorientation of the resin particles.

The data were correlated by an equation relating the height of a transfer unit to operating variables and the characteristics of the resin-ion system, and the results are given in graphical and tabular form.

directions, and thus the majority of the separated components  $A$  and  $B$  are carried to opposite ends of the contacting apparatus. In order that both product streams be fluid, it is necessary that ion  $B$  in the resin phase be retransferred to a solution. This requires a third component, say ion  $G$ , to elute or remove  $B$  from the effluent resin.

Thus in the simplest ion-exchange separation system, three components (ions  $A$ ,  $B$ , and  $G$ ) and two phases (resin and solution) are involved. The only design theory that is presently available to handle this complex system is the trace theory. As defined by Vermeulen and Hiester (12), the exchange of a trace component takes place when a resin saturated with a gross component ( $G$ ) contacts a solution containing a very small concentration of component  $A$  (and/or  $B$ ) in the presence of a very large concentration of component  $G$ . This leads to a linear relationship between the concentration of component  $A$  on the resin and its concentration in solution at equilibrium. The exchange

reaction for this case may best be represented as



with the equilibrium constant  $K_{AG}$  for this reaction being defined as

$$K_{AG} = \frac{(A \cdot \text{resin})(G+)}{(A+)(G \cdot \text{resin})} \quad (2)$$

Similar relations can be obtained for trace component  $B$ .

### MECHANISM AND RATE OF IONIC TRANSFER

In the exchange adsorption denoted by the chemical reaction, Equation (1), a sequence of ionic processes is involved in order to replace ion  $G$  on the resin by ion  $A$  in the fluid. These processes may be grouped into the following three steps:

1. External counterdiffusion of  $A$  and  $G$  through the fluid film surrounding the resin particle.
2. Exchange or "surface reaction" of  $A$  and  $G$ . This step normally takes place so rapidly that it does not affect the rate of exchange (1).

3. Internal counterdiffusion of  $A$  and  $G$  through the homogenous gel structure of the resin particle.

The effective rate of exchange will evidently be controlled mainly by the step that exerts the largest resistance to transfer and is therefore inherently the slowest. Obviously the rate equation is simplified by neglecting all but this rate-controlling resistance or by combining all the steps into one effective step with a single apparent rate.

Actually the rate relation for each of these conditions has the same general mathematical form, differing only in the specific definition of the rate constant,  $\kappa_A$ . The form of the generalized equation, originally published in reference (12), has been modified to present the resin and solution concentrations as equivalent fractions rather than directly as normal concentrations. In this form the equation is more closely analogous to equations derived for other diffusional rate processes:

$$\left[ \frac{d(y_A)}{d\tau} \right]_{\text{particle}} = \kappa_A \frac{c_2 f_B}{Q \rho_P (1 - f_B)} \left( x_A - \frac{y_A}{M_A} \right) \quad (3)$$

where  $y_A$  is the equivalent fraction of component  $A$  on the resin with respect to  $Q$ , the total ionic capacity of the resin per unit weight on an oven-dried basis;  $\tau$  is the residence time of the resin particle within the contacting zone;  $\kappa_A$  is a generalized transfer coefficient for  $A$  exchanging with  $G$ , in reciprocal time units;  $f_B$  is the void fraction of the total volume of the contacting zone and is equivalent to the fraction of the total volume occupied by solution; conversely,  $(1 - f_B)$  is the fraction of the total volume occupied by resin in the contacting zone;  $\rho_P$  is the density of the resin expressed as oven-dried weight per unit volume of swelled resin;  $x_A$  is the equivalent fraction of component  $A$  in solution with respect to the total ionic concentration of the solution,  $c_2$ ;  $M_A$  is the slope of the equilibrium line on a  $y-x$  plot as defined below.

Equation (3) may be simplified by the use of the dimensionless distribution ratio, or partition coefficient,  $D$ , as defined in reference (12):

$$D_A = \frac{M_A Q \rho_P (1 - f_B)}{c_2 f_B} \quad (4)$$

The modified Equation (3) then becomes

$$\left[ \frac{d(y_A)}{d\tau} \right]_{\text{particle}} = \kappa_A \frac{M_A}{D_A} \left( x_A - \frac{y_A}{M_A} \right) \quad (5)$$

In terms of the individual mass-trans-

fer coefficients, the corresponding equations are

$$\left[ \frac{d(y_A)}{d\tau} \right]_{\text{particle}} = (k_A)_{FA} \frac{M_A}{D_A} [x_A - (x_A)_i] \quad (6)$$

for fluid film diffusion and

$$\left[ \frac{d(y_A)}{d\tau} \right]_{\text{particle}} = (k_A)_{PA} [(y_A)_i - y_A] \quad (7)$$

for particle film diffusion, where  $(k_A)_F$  and  $(k_A)_P$  are the mass-transfer coefficients, in velocity units, based on fluid and particle diffusion respectively;  $a_F$  and  $a_P$  are the transfer areas per unit volume of contacting zone for diffusion through the fluid and particle respectively; and the subscript  $i$  denotes the interface. The term  $M_A/D_A$ , which is the ratio of the total equivalent capacities in the fluid and in the solid phases, is required in Equations (5) and (6) to put them on a consistent basis, i.e., in terms of the particle. The relations between the generalized over-all rate constant  $\kappa_A$  and the individual transfer coefficients are easily obtained from Equations (5) and (6) or (7), because at the interface

$$\begin{aligned} \left[ \frac{d(y_A)}{d\tau} \right]_{\text{particle}} &= \frac{x_A - y_A/M_A}{\frac{D_A}{M_A} \cdot \frac{1}{\kappa_A}} \\ &= \frac{x_A - y_A^*/M_A}{\frac{D_A}{M_A} \cdot \frac{1}{(k_A)_{FA} a_F}} = \frac{y_A^*/M_A - y_A/M_A}{\frac{1}{M_A} \cdot \frac{1}{(k_A)_{PA} a_P}} \\ &= \frac{x_A - y_A/M_A}{\frac{D_A}{M_A} \cdot \frac{1}{(k_A)_{FA} a_F} + \frac{1}{M_A} \cdot \frac{1}{(k_A)_{PA} a_P}} \end{aligned} \quad (8)$$

and thus

$$\frac{1}{\kappa_A} = \frac{1}{(k_A)_{FA} a_F} + \frac{1}{D_A} \cdot \frac{1}{(k_A)_{PA} a_P} \quad (9)$$

#### EQUILIBRIUM RELATIONS

In terms of equivalent fractions, the mass-action equilibrium relation, Equation (2), takes the form:

$$K_{AG} = \frac{y_A x_G}{x_A y_G} \quad (10)$$

where  $x_G/y_G$  is a constant under trace conditions.

This leads to the equilibrium relations

$$y_A^* = M_A x_A \quad (11)$$

or

$$x_A^* = \frac{y_A}{M_A} \quad (12)$$

where

$$M_A = \frac{K_{AG} y_G}{x_G}$$

These are Henry's law (or linear isotherm) forms, since  $M_A$ , the slope of the equilibrium line or the distribution coefficient, is a constant for a given trace-exchange system.

It should be noted that this form is equivalent to that obtained by setting the rate equation (5) equal to zero, i.e., assuming that the rate of exchange is zero or that the system is in equilibrium.

#### Design Considerations

##### COUNTERCURRENT OPERATION

In continuous countercurrent practice, a stream of ion-exchange resin of constant composition  $(y_A)_{\text{entr}}$  is fed into the top of a countercurrent contacting section at a constant volumetric rate of flow  $R_P$  and is removed from the bottom of the section at the same rate. Simultaneously, a solution stream of constant composition  $(x_A)_{\text{entr}}$  is introduced into the bottom of the section at a constant volumetric rate of flow  $R_F$  and at this same rate passes up through the column countercurrent to the resin and leaves the top. Diagrammatically this is shown in Figure 1 for a column having a height  $h$  and cross-sectional area  $S$ . Here  $(x_A)_{\text{exit}}$  is the composition of the effluent solution after it has passed through the column, which has a total inventory of resin  $hS(1 - f_B)$ , and  $(y_A)_{\text{exit}}$  is the composition of the effluent resin. The residence time for a resin particle in the column is the ratio of the total resin inventory to the resin flow rate.

There are two methods for predicting these exit compositions, the first, or dynamic, method based on the rate equation (5) where  $\tau$  is the statistical residence time of a resin particle in the countercurrent section and the second based on the assumption that the section is made up of a finite number of equilibrium contacts (similar to plates in a distillation column).

##### DYNAMIC METHOD

For the dynamic approach, a conservation equation and boundary conditions are needed in addition to the rate equation. At the steady state, i.e., no accumulation or depletion of  $A$  at any cross section in the column, the following differential material balance equation applies:

$$R_{PP} Q \frac{d(y_A)}{d\tau} = R_F C_2 \frac{d(x_A)}{d\tau} \quad (13)$$

This equation, in conjunction with the generalized rate equation (5) and the boundaries indicated in Figure 1, is now



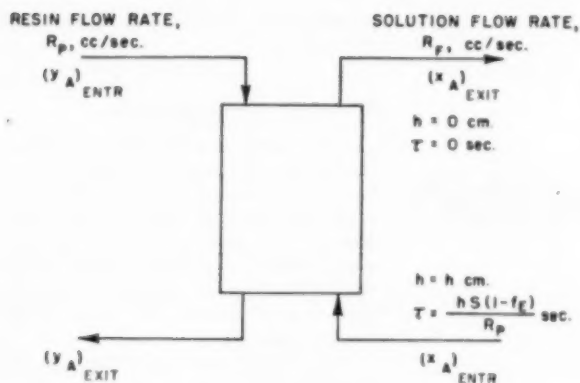


Fig. 1. Simple countercurrent operations.

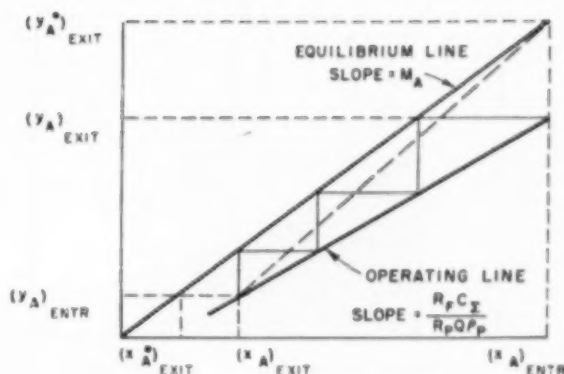


Fig. 2. McCabe-Thiele diagram for trace countercurrent ion exchange.

sufficient to define the behavior of this system. Colburn (3) has given the solution for a set of analogous equations, and in the present case the result is

$$\frac{E_A}{1-E_A} \ln \frac{E_A(1-\gamma_A)}{E_A-\gamma_A} = \frac{\kappa_A h S f_E}{R_p} = (Nt_A)_{OF} \quad (14)$$

where  $(Nt_A)_{OF}$  is the number of overall transfer units, based on the fluid film, as defined by Chilton and Colburn (2) and where  $\gamma_A$  is related to the terminal solution and resin concentration as follows:

$$\frac{(x_A)_{entr} - (x_A)_{exit}}{(x_A)_{entr} - (x_A^*)_{exit}} = \gamma_A = E_A \cdot \frac{(y_A)_{entr} - (y_A)_{exit}}{(y_A)_{entr} - (y_A^*)_{exit}} \quad (15)$$

Here

$$(x_A^*)_{exit} = (y_A)_{entr}/M_A$$

from Equation (12) and

$$(y_A^*)_{exit} = M_A(x_A)_{entr}$$

from Equation (11).

It will be observed that  $\gamma_A$  is the degree of approach to equilibrium transfer of component  $A$  in the solution phase, while the degree of approach in the resin phase is  $\gamma_A/E_A$ , because the resin concentrations are expressed on a different basis from that used for solutions.

The value of  $E_A$  in Equations (14) and (15) is the ratio of the slope of the equilibrium line to the slope of the operating line on a McCabe-Thiele  $y-x$  type plot. In terms of the operating variables concerned, this ratio is defined as

$$E_A = \frac{M_A}{R_f C_T / R_p Q P_p} = D_A \frac{R_p / (1-f_E)}{R_f / f_E} \quad (16)$$

It will be noted that the multiplier of

$D_A$  above is the ratio of the linear resin velocity to the linear solution velocity. When Equation (14) is used to replace  $\kappa_A$  in Equation (9), it becomes

$$\frac{h S f_E}{R_p} \cdot \frac{1}{(Nt_A)_{OF}} = \frac{1}{(k_A)_{FAF}} + \frac{1}{D_A} \cdot \frac{1}{(k_A)_{FAF}} \quad (17)$$

By analogy to the definition of the over-all number of transfer units, the individual transfer units should be the product of the film coefficient and residence time for the phase of interest. Thus

$$(Nt_A)_F = (k_A)_{FAF} \frac{h S f_E}{R_p} \quad (18)$$

for fluid-film diffusion controlling.

$$(Nt_A)_P = (k_A)_{FAF} \frac{h S (1-f_E)}{R_p} \quad (19)$$

for particle-film diffusion controlling.

Substituting these into Equation (17) and utilizing Equation (16) give the relation between the various transfer units as

$$\frac{1}{(Nt_A)_{OF}} = \frac{1}{(Nt_A)_F} + \frac{1}{E_A (Nt_A)_P} \quad (20)$$

#### EQUILIBRIUM CONTACT METHOD

Where discrete stages are involved in countercurrent contacting of resin and solution, the relations established by Kremser (8) for absorption of lean components can be converted to ion-exchange nomenclature. Under the assumption that complete equilibrium is attained in each discrete stage, the relation for the degree of approach to equilibrium transfer is

$$\gamma_A = E_A \frac{E_A^{N_G} - 1}{E_A^{N_G+1} - 1} \quad (21)$$

where  $N_G$  is the number of equilibrium contacts between the two phases. Rearrangement of Equation (21) gives a more appropriate form for determining  $N_G$  from  $\gamma_A$  and  $E_A$ .

$$N_G = \ln \left[ \frac{E_A - \gamma_A}{E_A(1-\gamma_A)} \right] / \ln E_A \quad (22)$$

The relation between theoretical contacts and transfer units is directly analogous to the relation in distillation; i.e., one theoretical contact produces a change in solution composition equal to the driving force at the point where the resin leaves the section,  $x-x^*$ ; whereas one transfer unit produces a change in solution composition equal to the average driving force,  $(x-x^*)_{avg}$ . A transfer unit and theoretical contact will be identical only when the slopes of equilibrium line and operating line are the same, i.e.,  $E = 1$ .

An exact relation between the number of transfer units and equilibrium contacts can be obtained by eliminating  $\gamma_A$  between Equations (14) and (22) to give

$$\frac{(Nt_A)_{OF}}{N_G} = \frac{E_A \ln E_A}{E_A - 1} \quad (23)$$

#### DESIGN CRITERIA

The McCabe-Thiele graphical method may be applied to the design of equipment for the separation of trace components by countercurrent ion exchange. Figure 2, for instance, illustrates the relation between the operating line and equilibrium isotherm when a trace ion  $A$  is being transferred from the solution phase to the countercurrent resin stream. The horizontal distance between the two lines represents the over-all driving force for ionic transfer based on the fluid film. The number of transfer units may be determined graphically, as indicated in Figure 3, by the procedure sug-

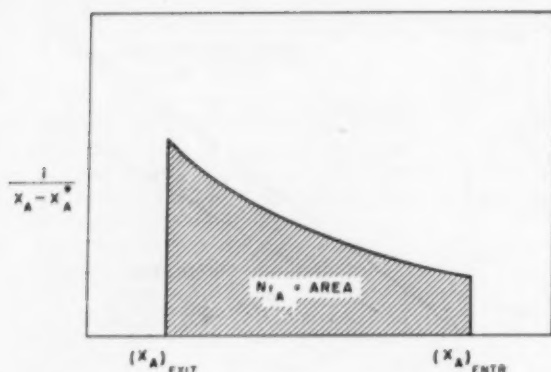


Fig. 3. Graphical determination of number of transfer units.

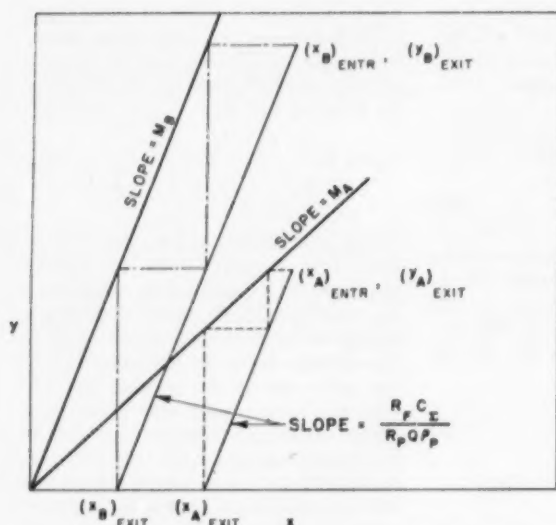


Fig. 4. Separation of trace components with two theoretical contacts.

gested by Selke and Bliss (10), although the use of Equation (14) to obtain  $(Nt_A)_{OP}$  is much more convenient.

The number of equilibrium contacts required to reduce the concentration of  $A$  from its feed value to the desired exit concentration may also be found graphically by stepping off the stages in the conventional manner or by using Equation (22).

For ionic transfer from solution to the resin, i.e., saturation, the operating line will lie below the equilibrium line. In order to have nearly complete removal of ion  $A$  from a feed solution, the entering resin must be nearly free of  $A$ , the slope of the equilibrium line must be greater than the slope of the operating line (i.e.,  $M_A > R_F C_Z / R_P Q_P Q$ ), and a large number of contacts will generally be required. Conversely, the operating line will be above the equilibrium line for elution or stripping of ions from the

resin. Nearly complete regeneration requires an eluting solution free of the component concerned, a large number of contacts, and a slope ratio such that  $M_A < R_F C_Z / R_P Q_P Q$ .

A hypothetical separation of trace ions  $A$  and  $B$  is illustrated in Figure 4 for a saturation section having two theoretical contacts. The two ions are present in equimolar concentrations in the feed, and the entering resin is free of  $A$  and  $B$ . The operating lines for the two ions are parallel. Because the slope of the equilibrium line for  $B$  is greater than for  $A$ , the concentration of the solution is reduced much further in  $B$  than in  $A$ . Thus the effluent solution is enriched in  $A$ , and the effluent resin is enriched in  $B$ .

The maximum slope of the operating line, the  $R_F C_Z / R_P Q_P Q$  ratio, which will give the desired effluent solution concentration may also be determined

graphically as shown by the dashed line in Figure 2.

#### METHOD OF CORRELATING DATA

A correlation of continuous-ion-exchange data involves the relation of the height of a transfer unit to the Reynolds and Schmidt numbers and other dimensionless parameters. This correlation is based on Equation (17), which relates the over-all number of transfer units to the fluid and particle-film coefficients  $k_F$  and  $k_P$ .

The fundamental definitions of the film coefficients are

$$(k_A)_F = \frac{(D_A)_F}{B_F} \quad (24)$$

$$(k_A)_P = \frac{(D_A)_P}{B_P} \quad (25)$$

where  $(D_A)_F$  and  $(D_A)_P$  are respectively the counterdiffusivities of ions  $A$  and  $G$  in the fluid and in the particle and where  $B_F$  and  $B_P$  are the effective thicknesses of the fluid and particle films.

The effective transfer area per unit volume of bed has been assumed to be identical for both the fluid and particle films; i.e.,  $a = a_F = a_P$ . Moreover, this transfer area has been assumed to be the phase interface or the surface of the resin particle. Using these assumptions Ergun (5) has shown that

$$a = \frac{6(1-f_R)}{d_P} \quad (26)$$

Taking into account Equations (24) to (26), Equation (17) may then be modified as follows:

$$\frac{h S f_R}{(Nt_A)_{OP} R_F} = \frac{d_P}{6(1-f_R)} \cdot \frac{B_F}{(D_A)_F} + \frac{1}{D_A} \cdot \frac{d_P}{6(1-f_R)} \cdot \frac{B_P}{(D_A)_P} \quad (27)$$

After one multiplies through by  $1/d_P$  to obtain ratios of film thickness to particle diameter and by  $[a(D_A)_P D_A]$  to obtain a dimensionless form, rearrangement of terms leads to

$$\left[ \frac{h}{(Nt_A)_{OP} d_P} \right] \frac{D_A S f_R (D_A)_P 6(1-f_R)}{d_P R_F} = D_A \frac{(D_A)_P}{(D_A)_F} \cdot \frac{B_F}{d_P} + \frac{B_P}{d_P} \quad (28)$$

It has been noted (2, 13) that the fluid-film-thickness ratio,  $B_F/d_P$ , varies inversely with the Reynolds and Schmidt numbers, although the particle-film-thickness ratio,  $B_P/d_P$ , is assumed to be a constant for spherical particles. Thus

$$\frac{B_P}{d_P} = \text{a constant, } \beta \quad (29)$$

and

$$\frac{B_F}{d_P} = a(Rc)^{-m}(Sc)^{-n} \quad (30)$$

where  $a$  is a constant of proportionality,  $m$  and  $n$  denote powers, and

$$\begin{aligned} Rc &= \frac{r_h u_p}{\mu} \\ &= \left[ \frac{d_P f_E}{6(1-f_E)} \right] \left[ \frac{R_F + \frac{R_P}{(1-f_E)}}{S} \right] \frac{\rho}{\mu} \\ &= \frac{d_P R_F \rho}{6(1-f_E) S \mu} \left[ 1 + \frac{R_P/(1-f_E)}{R_F/f_E} \right] \end{aligned} \quad (31)$$

and

$$Sc = \frac{\mu}{\rho(D_A)_F} \quad (32)$$

The terms involved in the basic Reynolds and Schmidt groups have the usual definitions:  $r_h$  being the hydraulic radius,  $u$  the true average point velocity,  $\rho$  the solution specific gravity, and  $\mu$  the solution viscosity, all in consistent units. The specific definition of the hydraulic radius is that proposed by Ergun (5); it is equivalent to the ratio of the volume occupied by the fluid in the bed to the total surface wetted. The point velocity for countercurrent operation was taken as the sum of the fluid and particle velocities.

When Equations (28 to 30) are combined and the numerator and denominator of the left-hand side are multiplied by  $(D_A)_F$ , the correlation equation becomes

$$D_A \frac{(D_A)_P}{(D_A)_F} \left[ \frac{hf_E}{(Nt_A)_{OF} d_P} \right] \left[ \frac{6(1-f_E)S(D_A)_F}{d_P R_F} \right] = a D_A \frac{(D_A)_P}{(D_A)_F} (Rc)^{-m} (Sc)^{-n} + \beta \quad (33)$$

Graphically the relation may be represented by a straight line if the left-hand side is plotted as the ordinate against

$$D_A \frac{(D_A)_P}{(D_A)_F} (Rc)^{-m} (Sc)^{-n}$$

as the abscissa. The resultant line will have a slope  $\alpha$  and an intercept  $\beta$ .

## Equipment

### GENERAL

As in any process development, the physical design of the separation apparatus changed with experience. The current equipment reflects the best features of three earlier models of continuous countercurrent column apparatus. The first model was a glass column in which the resin was transferred by means of a water-operated Venturi jet. In the second model improvements were made to reduce dilution due to the water transporting the resin. A mechani-

cal screw lift was used for transferring resin in the third model, but too much solution was pumped by the screw lift and the resin attrition rate was high.

A new resin-transfer device was developed to overcome the disadvantages of the screw lift. This was the resin metering and dewatering valve shown in Figures 5 and 6. The design of this valve was based on a metering device used by Stanton (11) in his studies of countercurrent ion exchange. Made largely of acrylic resin, the valve consisted of a cylindrical rotor and a case. Through the center of the rotor and perpendicular to its longitudinal axis, a hole was bored. A glass disk containing a multitude of small holes was retained at the center of this bore. The case was made to fit the rotor with a close tolerance and was provided with six channels between the periphery of the rotor and the outside of the case.

As the rotor turned in a clockwise direction, the following sequence of operations occurred. Starting with the bore of the rotor in a vertical position, an aliquot of resin slurry flowed into the upper half of the bore through the inlet

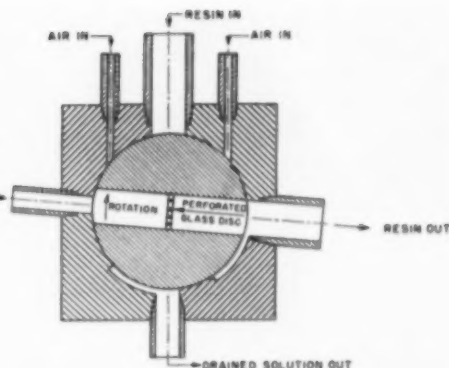


Fig. 6. Resin metering and dewatering valve.



nipple. The resin was retained on the glass disk, and some of the solution in the slurry drained through the perforations to the bottom outlet. As the bore of the rotor passed under the right air inlet, air pressure was applied to this inlet by means of a cam arrangement which actuated a solenoid air valve. The air pressure forced the residual interstitial solution out of the resin into the slot on the opposite side and thence out the same bottom outlet. Just as the bore passed beyond the right air inlet, the cam arrangement caused the solenoid valve to close, preventing air leakage around the rotor. The bore next became aligned with the resin outlet and, at the opposite end, with the flush solution inlet. This solution under a constant head carried the resin slug from the valve as a slurry. The flushing operation left the bore partially filled with washout solution, which was displaced when the new top of the bore rotated under the left air inlet, to which the air flow was also controlled by the cam arrangement. The surge of air blew the residual solution from the bore into the slot opposite the air inlet and thence out the same slurry outlet. This completed one cycle, the next operation being the filling of the new upper half of the rotor bore. Therefore, there were two complete cycles per revolution of the valve rotor.

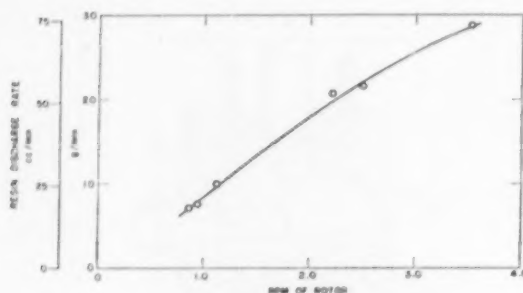


Fig. 7. Performance of resin metering valve.

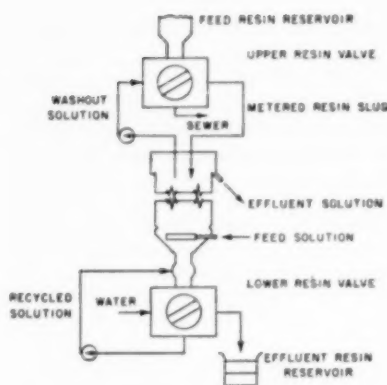


Fig. 8. Schematic diagram of column assembly.

The rotor was driven by a  $\frac{1}{4}$ -hp. motor through a variable-speed torque converter and reduction gears. The rate of resin transfer was proportional to the speed of rotation of the rotor, as shown in Figure 7. The performance of the valve was evaluated experimentally, and no measurable carry-over of the solution originally in the feed slurry to the discharged slurry was found other than what the filtered resin would normally carry.

#### EXPERIMENTAL UNIT

Two of these resin valves were incorporated into a column assembly for evaluating the effect of a number of variables on continuous countercurrent ion exchange in a single column. In this column only one phase at a time of the cyclic operations involved in the completely continuous separation of ions was studied (e.g., the saturation of G resin with B and A ions), because the column variables which affect the saturation step similarly affect the elution or regeneration step and other phases of the cyclic process.

The column assembly is indicated schematically in Figure 8 and is pictured in Figure 9. The Pyrex shell was 9.5 cm. I.D., and the distance between the feed inlet and the overflow ring was 122 cm. The feed solution was introduced through a 7.5-cm. ring of glass tubing having an upper surface of porous fritted glass. The distributor was provided with an inlet tube which extended through the wall of the column.

At the top of the column the exhausted solution spilled into the overflow ring and was collected. The resin was introduced into the top of the column from an overhead slurry storage through one of the metering and de-watering valves. A corresponding valve served to remove the resin from the bottom of the column. To avoid accumulation or depletion of the resin inventory in the column, the resin-throughput rates of the two resin valves were always equalized.

Solution pumped from near the top of the column to a small overhead reservoir was used to wash the resin from the upper valve into the top of the column. Thus the washout solution, which was of substantially the same composition as the exhausted feed, was recycled.

The solution drained from the resin entering the lower valve was recycled to the column, which it reentered at the base of the lower taper into an expanded bulb, which minimized disturbance within the column.

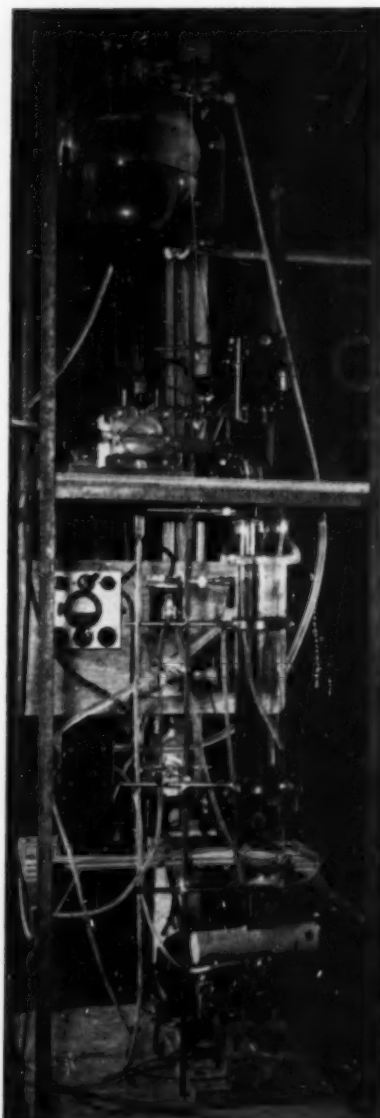
Contact between the resin and solution was obtained in a column containing a dense moving bed of resin through which the solution flowed. As a layer of this resin bed was removed from the bottom of the column by the lower valve, it was replaced with a layer of resin at the top of the bed, resulting in a net downward flow of the resin. For a run the column was first filled with feed solution, which then was metered in at a constant rate, entering through the fritted glass ring and overflowing at the top at the same rate. Resin from the overhead supply was metered into the top of the column at a constant rate and fell to the top of the moving resin bed. This was maintained at the desired height above the solution feed distributor by removal of the resin from the base of the column at the same rate that it was supplied.

A column insert, termed the tapped screen (Figure 10), was designed to promote better contact between resin and solution under moving-bed conditions. It consisted of 5 disks of 16-mesh Monel screen spaced 5 cm. apart and supported with Monel rods. A central rod passing through the screens was attached to them with washers. A light hammer, actuated by a motor-driven cam, tapped the central rod 30 to 200 times/min.; for higher rates, a vibrator, which gave a tapping frequency of greater than 1,000/min., was used. These impacts were transferred to the screens. With this assembly in place in the column, conventional moving-bed runs were made in which one or more of the screens were contained within the moving bed of resin. The vibration of the screens tended to cause reorientation of the resin particles and redistribution of the fluid, thus reducing channeling.

Some attrition of the resin was observed during its passage through the resin valves and the tapped screen. With new resin this amounted to about 0.1% per passage. More detailed information on resin attrition is contained in Appendix A.\*

\*See footnote on page 139.

Fig. 9. Column assembly.





## MULTIUNIT OPERATIONS

The studies described above have been concerned largely with only one phase of a continuous ion-separation process, namely, the transfer of the ions, trace or otherwise, from the feed solution to the resin. This has been termed saturation. As in the more familiar fixed-bed processes, the resin must undergo alternate saturation and elution. The simplest system for continuous ion separation involves two countercurrent contacting units, one for saturating and one for eluting the resin.

Such a system is indicated schematically in Figure 11. In operation, a feed stream containing a mixture of ions A and B would be introduced into the bottom of the saturating section. The ion, say A, least strongly held by the resin would be carried largely by the rising solution. Thus the effluent solution (or upper product) from the saturating section would be enriched in ion A and the effluent resin from this section would be enriched in ion B. The transfer of ion B to the solution phase would involve another exchange process in which the spent resin (enriched in B) would be passed through the second countercurrent contactor comprising the eluting section. The spent elutant from this section would then be enriched in B and could be considered as a lower product stream. The resin removed from the regenerating section, now eluted, would be returned as feed resin for the saturating section, which would thus permit continuous recirculation of the solid phase. This two-section unit has been discussed in detail in a companion paper (6).

Other possibilities are apparent in the arrangement not only of these two sections, but of three- and four-section units. Although it is possible to apply the principle of reflux with the two-section unit, the more complex units are designed specifically to provide reflux of a portion of the ions from one or both product streams into the sections from which the respective streams emerged. Dickel (4) has discussed this principle of reflux in countercurrent ion-exchange separations. An example of a possible four-section arrangement is shown in Figure 12.

## Experimental Procedure

### GENERAL

The experimental work was based on the separation of  $\text{Li}^+$  and  $\text{K}^+$  in trace concentrations, with respect to the  $\text{H}^+$  carrier or gross component. Elution was also conducted with  $\text{H}^+$ . This particular system was selected for several reasons: the three ions are equivalent, thus simplifying the exchange mechanism;  $\text{Li}^+$  and  $\text{K}^+$  are both available in pure forms at reasonable costs, may be analyzed readily by flame photometry, and, being the first and third elements in the alkali metal series, differ sufficiently to make separation feasible; and  $\text{H}^+$  is used as the carrier and elutant because of its ease of analysis. The  $\text{Li}^+$  is least strongly held by the resin and thus corresponds to A ion in the general discussion above,  $\text{K}^+$  corresponds with

Fig. 10. Tapped-screen assembly.

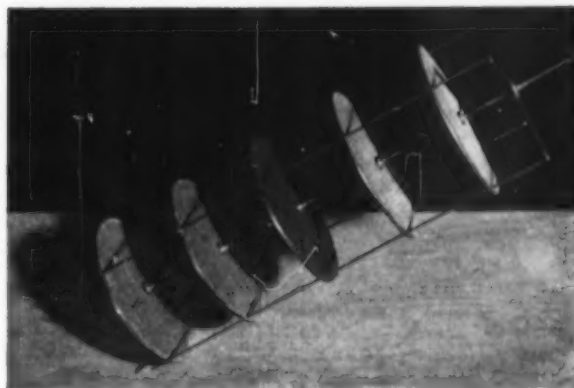
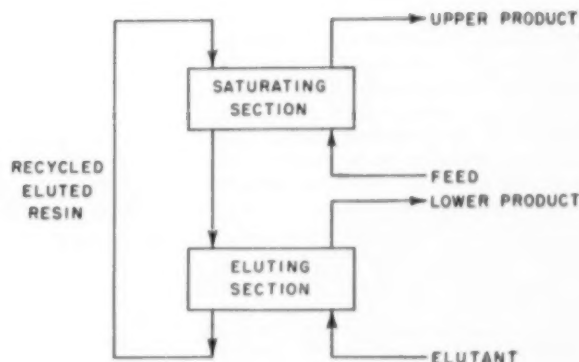


Fig. 11. Countercurrent operations in a two-section unit.

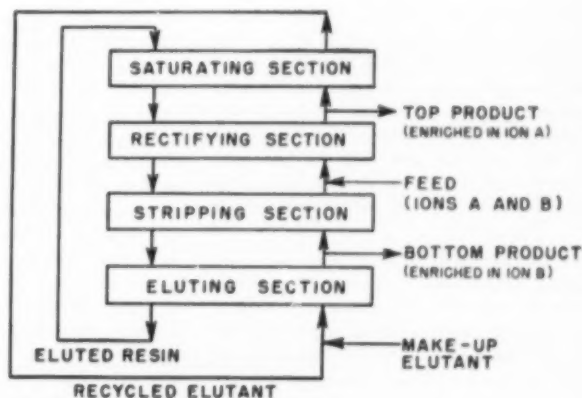


the hypothetical B ion and  $\text{H}^+$  is the G ion.

Chempre C-20 cation-exchange resin, a sulfonated polystyrene-base type, was used throughout the studies. The resin was wet-screened 16 to 35 mesh, and so the average wet-particle diameter was 0.07 cm. The solution diffusivities for  $\text{Li}^+$ ,  $\text{K}^+$  and  $\text{H}^+$  were taken from the International Critical Tables and were averaged for the ion pairs concerned:  $(D_{\text{Li}})_F = 1.85 \times 10^{-5}$  and  $(D_{\text{K}})_F = 2.18 \times 10^{-5}$  sq.

cm./sec. The ratio of the resin and solution average diffusivities,  $(D_A)_F/(D_A)_F$ , was found by several of the present authors (7) to be  $\sim 0.19$  for univalent ions and this type of resin. The resulting resin diffusivities were then  $(D_{\text{Li}})_R = 3.46 \times 10^{-6}$  and  $(D_{\text{K}})_R = 4.08 \times 10^{-6}$  sq.cm./sec. The settled resin had a void fraction,  $f_{\text{R}}$ , of 0.39 and a density,  $\rho_{\text{R}}$ , of 0.64 g. oven-dried weight per c.c. of true wet-resin volume.

Fig. 12. Four-section ion-separation unit.



## METHODS OF ANALYSIS

The following analytical procedures were developed to assess the concentration of lithium, potassium, and hydrogen ions in the solutions and on the resins. These cations were present in the solutions as chlorides.

The solutions were analyzed for the alkali metal content with a Beckman DU spectrophotometer with a flame attachment. Lithium was determined at 673 m $\mu$  at a slit width of 0.15 mm. and potassium was read at 771 m $\mu$  at a slit width of 0.06 mm. It was necessary to make corrections for interference (by reinforcement) of the hydrogen chloride on the emission, and for mutual interference of the metal ions. The H<sup>+</sup> correction was made by analyzing the unknown solutions against lithium and potassium standard solutions containing 1.0 N HCl, since this was the H<sup>+</sup> concentration in nearly all the experimental solutions. If the H<sup>+</sup> content of the unknown differed from 1.0 N by more than 10%, the solution was adjusted to 1.0 N by the addition of measured volumes of distilled water or hydrochloric acid as required and was then analyzed for the metal ions. Corrections for the mutual interference of the metal ions were made with the aid of a number of calibration curves, which had been prepared by the experimental determination of the degree of interference over a very wide range and ratio of concentrations. The exact H<sup>+</sup> concentrations were determined with a Beckman automatic titrator. Concentrations in solution were reported as milliequivalents per cubic centimeter.

Resin samples were analyzed by eluting water-washed aliquots of about 25 c.c. with 250 ml. of 2N HCl. The resulting elutants were diluted to 1.0 N H<sup>+</sup>, and were analyzed for metallic ion concentrations as described above. The eluted aliquots were oven-dried, and resin concentrations were reported as milliequivalents per gram.\* The hydrogen ion concentration on the resin, although seldom of interest in trace studies, was obtained as the difference between the ultimate capacity of the resin and to total metal ion concentration.

## RESIN BEHAVIOR

The ultimate capacity of the resin represents the total number of ion-exchange positions available on a unit quantity of resin. This was determined by first converting a portion of resin entirely to the hydrogen form by complete elution of metal ions. Then a portion of this resin was contacted in a fixed bed with a large quantity of calcium chloride solution to displace the H<sup>+</sup>. The effluent solution was titrated for the H<sup>+</sup> concentration, and the total milliequivalents of H<sup>+</sup> removed were calculated. The resin aliquot was oven-dried, and the ultimate

\* Where necessary, as in resin flow rates, settled volumes were converted to a weight basis by means of a density factor. This factor, 0.39 g. dry resin/c.c. settled volume, was determined experimentally for a number of samples and was found to have a maximum deviation of about 1%.

capacity was then reported as milliequivalents per gram on the dry basis. This procedure is similar to that suggested by Kunin and Myers (9). For the resin used, this capacity was 5.11 milliequivalents per gram.

The distribution coefficients for the Li<sup>+</sup>—H<sup>+</sup>, and K<sup>+</sup>—H<sup>+</sup> pairs under study were determined by batch contacting. Separate portions of a resin sample in the hydrogen form were equilibrated by shaking for about 8 hr. with solutions containing various trace concentrations of lithium and potassium ions in 1.0 N HCl. The equilibrated resin and solution samples were then separated and analyzed by the foregoing procedures. The results, plotted as equivalent fraction of the trace ion on the resin, based on the ultimate capacity, vs. equivalent fraction of this ion in the solution, based on total ionic concentration, gave the curves shown in Figure 13. The slope of the Li<sup>+</sup> curve, which

is the distribution coefficient,  $M_{LiH}$ , is 0.87. Similarly, the potassium-hydrogen distribution coefficient,  $M_{KH}$ , is 3.30.

At the higher solution-flow velocities used for most of the later runs, expansion of the resin bed was encountered. This affected the external void fraction. The measurement of bed expansion was difficult because of the oscillating level of the resin at high throughputs. The data obtained from the experimental runs and from special hydraulic tests are indicated in terms of the external void fraction in Figure 14. Up to 0.035 cm./sec., no effect on the void fraction was observed. Beyond that solution velocity, an average curve was drawn through the points, and the smoothed data were used in the interpretation of the experimental results. Above 0.35 cm./sec., resin was carried out of the top of the column at a substantial rate.

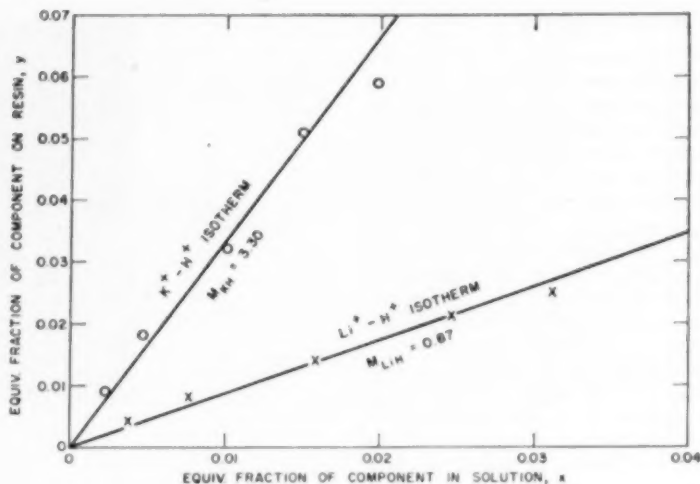


Fig. 13. Equilibrium isotherms.

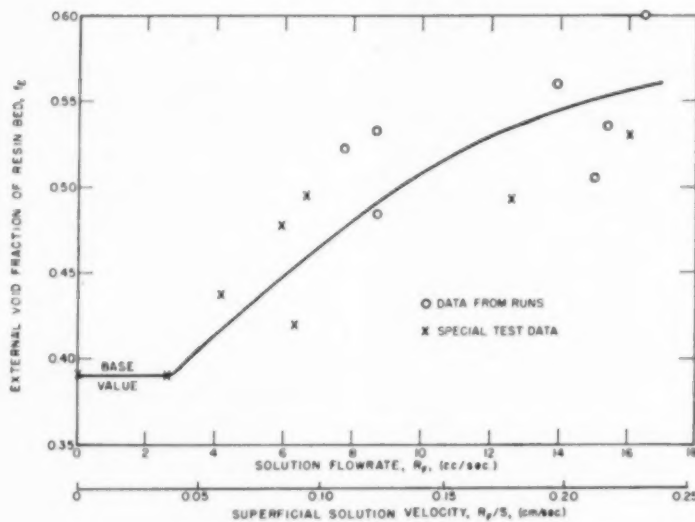


Fig. 14. Effect of flow rate on void fraction.

Table 1.—Experimental Conditions

Run No.	Bed Height $h$ cm.	Total Ionic Concentration $C$ meq./c.c.	Volumetric Flow Rates		$E$ Values		Void Fraction $f_B$	Tapping Rate taps/min.
			Solution $R_p$ c.c./sec.	Resin $R_p$ c.c./sec.	$E_{Li}$	$E_K$		
1	12.7	1.00	2.07	0.221	0.306	1.16	0.39	*
2	12.7	1.06	1.37	0.212	0.419	1.39	0.39	200
3	7.6	1.08	1.36	0.214	0.436	1.65	0.39	200
4	7.6	1.08	1.38	0.380	0.721	2.74	0.39	200
5	6.8	2.13	1.97	0.218	0.148	0.561	0.39	200
6**	7.6	1.03	0.78	0.347	1.23	4.65	0.39	200
7	7.6	1.00	1.58	0.204	0.374	1.42	0.39	50
8	6.4	1.10	1.61	0.330	0.539	2.04	0.39	200
10	28.0	1.04	15.05	0.742	0.135	0.512	0.50	200
11	21.6	1.00	15.40	0.651	0.121	0.458	0.54	200
12	16.5	1.04	8.69	0.705	0.223	0.845	0.53	200
13	17.8	1.06	7.73	0.732	0.228	0.866	0.52	*
17	21.0	0.98	16.48	0.562	0.100	0.379	0.60	*
19	21.6	1.06	13.92	0.642	0.124	0.470	0.56	*
20	16.5	1.08	8.83	0.698	0.210	0.796	0.49	*
21	7.6	0.70	2.66	0.291	0.442	1.68	0.39	1000

\* Tapped screen assembly omitted.

\*\* Elution run.

## OPERATION OF EQUIPMENT

All the experimental runs were made under similar conditions, in most the column being operated as a saturation section. The prepared resin, essentially in the hydrogen form, was metered into the top of the column at 0.2 to 0.7 c.c./sec. and was withdrawn at the same rate through the lower resin valve. Feed solutions usually were made up to have the approximate composition 0.03 N  $Li^+$ , 0.03 N  $K^+$  and 1.0 N  $H^+$ , and the exact composition was then determined by analysis. Solution flow rates, measured with a rotameter, ranged from 0.8 to 16.5 c.c./sec., equivalent to superficial velocities of 0.01 to 0.23 cm./sec. through the column. Elution runs were also made in which resin partially saturated with  $Li^+$  and  $K^+$  was passed countercurrently to an acid feed solution.

Each run was started with the column full of feed solution and with the inventory of resin in the base of the column at the level to be maintained during the run. Both resin valves were started simultaneously when the solution began to overflow at the top of the column. Every 15 min. (5 min. at the higher flow rates) the effluent solution and the slurry of exhausted resin were collected. The volumes of the effluent solution and the slurry and the settled volume of the resin in the slurry (obtained by tapping the graduate) were recorded. In addition, a portion of the resin was vacuum filtered and held for analysis. Samples of the effluent and supernatant slurry solutions were also retained.

The concentrations of the metal ions in all the samples and the concentration of  $H^+$  in the solution samples were determined by the procedures described. A run was continued until there was reasonable assurance from past experience that the steady state had been attained. The length of the runs varied from 1 to 3 hr. The runs were made with the top level of resin maintained constant between 6 and 28 cm. above the feed-solution inlet. The feed resin entering the column fell freely

through the rising solution to the top of the moving bed of resin. The residence time of a resin particle in the moving bed was 10 to 45 min., and the solution residence time was 1 to 4 min. The experimental procedure for those runs in which the tapped screen was used to improve contact did not differ from that for the simple moving-bed runs except in the continuous operation of the tapping hammer. The operating conditions for the runs are listed in Table 1.

## Interpretation of Results

## TREATMENT OF DATA

The experimental data were obtained in terms of flow rates and concentrations (later converted to equivalent fractions), a typical set of data, from Run 1, being represented in Figure 15. The upper portion of the figure shows the change in the equivalent fractions of the trace ions in the effluent resin with

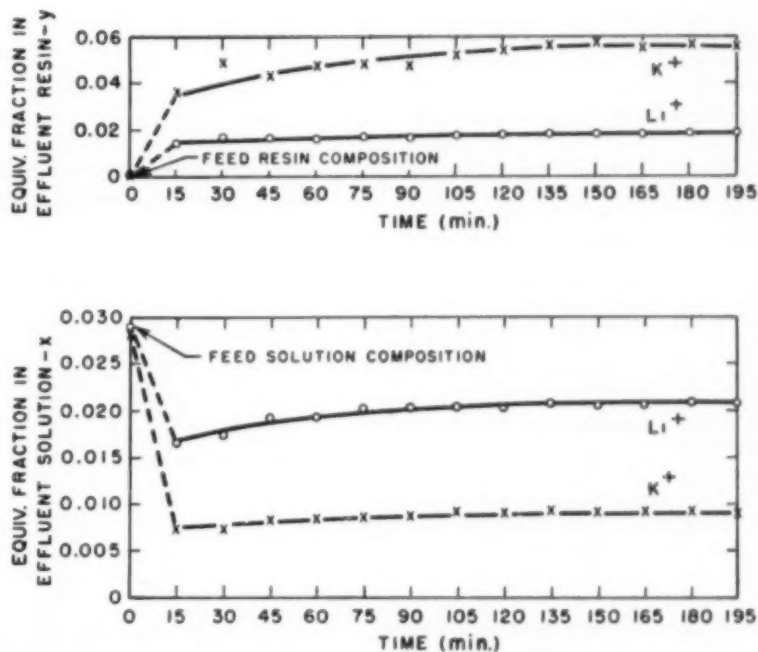


Fig. 15. Effluent compositions vs. time for run 1.

time, and the lower set of curves relates the corresponding changes on the effluent solution to the time of operation.

The equivalent fraction of the trace ions in the effluent solution and resin at the steady state were used to determine  $\gamma$  from Equation (15). For a given run, four values of  $\gamma$  were obtained: one based on the change in the fraction of  $\text{Li}^+$  in solution, one based on the change in the fraction of  $\text{K}^+$  in the solution, and the two corresponding values obtained from the resin-concentration information. The two  $\gamma$  values based on  $\text{Li}^+$  were averaged, as were the two  $\gamma$  values based on  $\text{K}^+$ , in order to compensate for the deviation of the output-input balance for each ion from 100%. Balances ranged from 89 to 111% with an average deviation of 3%. The  $E$  ratio for each ion was calculated from the distribution coefficient and the equivalent flow rates according to Equation (16).

Then, the number of over-all transfer units and equilibrium contacts was calculated by Equations (14) and (22), respectively, from the  $E$  values and averaged  $\gamma$  values for each ion. The results for several of the runs showed nearly complete approach to equilibrium transfer, i.e.,  $\gamma \rightarrow 1$  or  $\gamma/E \rightarrow 1$ , and thus apparently an infinite  $N_O$  or  $N_I$ . This, of course, is impossible, and so the results must reflect the experimental uncertainties.

The proper interpretation of the results is certainly that a very large number of contacts or transfer units was obtained, the exact number being difficult to determine because of the limit of analytical accuracy. In the case of Run 2, for instance, an average  $\gamma_K$  value of 1.00 was obtained, indicating equilibrium. If this  $\gamma_K$  had been 0.99 at the same equivalent flow rates, the following values would have been indicated:

$(N_O)_K = 7.9$ ,  $(N_I)_K = 10.6$ . Since  $E_{Li}$ , the ratio of the distribution coefficient to slope of the material balance line, was less than one, it represented the limiting value of  $\gamma_{Li}$  for this run. The experimental  $(\gamma/E)_{Li} = 1.00$  showed that the maximum possible transfer of the lithium ions was obtained. Here, if  $(\gamma/E)_{Li}$  had been 0.99, the  $(N_O)_{Li}$  would have been 4.7 and the  $(N_I)_{Li}$  3.0. These finite values are estimates and were inserted in Table 1 in place of the apparently infinite  $N_O$  and  $N_I$  indicated directly by the actual data.

The results of the experimental runs are given in Table 2 in terms of enrichment and recovery factors and over-all numbers of transfer units and contacts. The values were calculated to the second decimal place and rounded to the first; the estimated values are indicated by asterisks.

$$D_A \frac{(D_A)_P}{(D_A)_F} \left[ \frac{hf_B}{(N_I)_O d_P} \right] \left[ \frac{6(1-f_B)S(D_A)_F}{d_P R_F} \right] \text{ vs. } D_A \frac{(D_A)_P}{(D_A)_F} (Re)^{-0.5} (Sc)^{-0.5}$$

#### CORRELATION OF DATA

It was not possible to make direct use of the proposed correlation relation (33), because the experimental data did not permit a conclusive choice of the powers for the Reynolds and Schmidt numbers.

However, several of the present authors (7) have shown that for fixed-bed ion exchange under trace conditions a modified form of Equation (33) also applies; i.e.,

$$D_A \frac{(D_A)_P}{(D_A)_F} \left[ \frac{hf_B}{s_A d_P} \right] \left[ \frac{6(1-f_B)S(D_A)_F}{d_P R} \right] = a' D_A \frac{(D_A)_P}{(D_A)_F} (Re)^{-m} (Sc)^{-n} + \beta' \quad (34)$$

where  $s$  is the number of fixed-bed transfer units and  $R$  is the solution flow rate.\* They found that the best fit to data available in the literature was obtained with  $m = n = 0.5$ ,  $a' = 0.29$  and  $\beta' = 0.04$ .

It will be noticed that the preceding relation is identical with Equation (33) except for the two terms peculiar to fixed-bed exchange and defined above.

In view of these fixed-bed results, the power of both the  $Re$  and  $Sc$  numbers was selected as 0.5 for the correlation of the moving-bed data. Initially only one set of related moving-bed data was used. This was obtained in the runs for which the tapped screen assembly was operated at a tapping rate of 200/min. and in which the bed expansion was negligible; it was the largest group of such related data. The experimental results for these runs were plotted as

on linear coordinates, as shown in Figure 16. The method of averages was used to locate the correlation line, and its slope and intercept,  $a$  and  $\beta$ , were found to be 1.6 and 0.6 respectively.

A replot of this correlation line on log-log coordinates, Figure 17, reveals more clearly the two diffusional regions. The horizontal portion of the curve, below abscissa values of 0.03, is the region where internal diffusion controls; above abscissa values of 3.0 the 45° line represents the region where external ion controls.

\* Obviously the Reynolds number used here is the same as that in Equation (31) except that  $R_F$  is zero and  $R_F$  has been replaced by  $R$  so that the average velocity is now  $R/t_{BS}$ .

Table 2.—Experimental Results  
Number and Height of Over-all  
Transfer Units

Run No.	Enrichment of $\text{Li}^+$ in effluent soln.		Recovery of $\text{Li}^+$ in effluent soln.		cm. bed height				Number of Equil. Contacts		Steady State Output/Input Ratio	
	$(X_{Li}/X_K)_{\text{effluent}}$	$(X_{Li}/X_K)_{\text{effluent}}$	$(X_{Li}/X_K)_{\text{effluent}}$	$(X_{Li}/X_K)_{\text{effluent}}$	$(N_I)_{Li}$	$(N_I)_K$	$(H_I)_{Li}$	$(H_I)_K$	$(N_O)_{Li}$	$(N_O)_K$	$\text{Li}^+$	$\text{K}^+$
1	4.7	0.71	0.79	2.2	16	5.8	1.5	2.1	0.94	1.00		
2	10.1	0.55	3.0*	10.6*	4.2	1.2	4.7*	7.9*	0.98	1.11		
3	6.9	0.56	2.0	5.8	3.8	1.3	3.1	4.5	0.91	1.03		
4	3.1	0.41	1.8	7.2*	4.2	1.1	2.2	4.1*	1.00	1.07		
5	1.6	0.84	0.8*	1.2	8.8	5.7	2.3*	1.6	1.01	0.98		
6**	...	...	3.2	5.5*	2.4	1.4	3.6	2.8*	0.89	0.99		
7	6.9	0.62	1.1	3.5	6.8	2.2	1.9	2.9	0.99	0.99		
8	6.2	0.50	1.7	3.6	3.7	1.8	2.1	2.6	0.97	0.98		
10	1.6	0.88	0.32	1.9	88	15	1.0	2.7	1.02	1.03		
11	1.4	0.90	0.25	1.1	86	21	0.8	1.6	1.02	0.94		
12	2.5	0.82	0.45	2.2	37	7.5	1.0	2.7	1.06	1.00		
13	2.6	0.78	0.98	2.8	18	6.4	1.8	2.9	1.01	0.99		
17	1.4	0.90	0.47	1.1	45	19	1.9	1.9	0.99	0.99		
19	1.1	0.90	0.27	0.81	80	27	0.9	1.6	1.02	1.02		
20	2.0	0.82	0.51	1.8	32	9.3	1.2	2.0	0.90	0.99		
21	7.2	0.65	1.16	3.3	6.5	2.3	1.8	2.5	0.99	0.91		

\* Based on assumption that  $\gamma = 0.99$  or  $\gamma/E = 0.99$

\*\* Elution run.



In this figure the experimental data for all the moving-bed runs are represented, including runs at high and low flow rates, at high and low tapping rates, and those in which the screen assembly was omitted. As can be seen, the original correlation line represents these data equally well except for the one run (No. 1) made without the tapped-screen assembly at the low flow rate.

It is apparent that most of the present runs fall in the transition region. The deviations of the data from the curve are attributed largely to the uncertainties of the experimental results. As pointed out above, wherever the approach to equilibrium indicated by the data was 1.0 or higher, the  $Nt$  value was calculated on the assumption that the actual approach was 0.99. These adjusted data are identified by the underlined points in Figure 16.

For the moving-bed runs, involving either the tapped screen or high flow rates, the data can best be represented by

$$D_A \frac{(D_A)_P}{(D_A)_F} \left[ \frac{hf_E}{(Nt_A)_{OF} d_P} \right] \left[ \frac{6(1-f_E)S(D_A)_F}{d_P R_F} \right] = 1.6 D_A \frac{(D_A)_P}{(D_A)_F} (Re \cdot Sc)^{-0.5} + 0.6 \quad (35)$$

The Reynolds and Schmidt numbers having been assumed to have the same powers, their product, the Peclet prime number, can be used where required,

$$Re \cdot Sc = \left[ \frac{d_P R_F}{6(1-f_E)S(D_A)_F} \right] \left[ 1 + \frac{R_P/(1-f_E)}{R_F/f_E} \right] = Pe' \quad (36)$$

thus eliminating  $\rho$  and  $\mu$  from the expression.

For convenience, Equation (35) can be rearranged into a transfer-height form, since  $Ht = h/Nt$

$$\left[ \frac{(Ht_A)_{OF}}{d_P} \right] = \frac{1.6}{f_E (Re \cdot Sc)^{0.5}} \left[ \frac{d_P R_F}{6(1-f_E)S(D_A)_F} \right] + \frac{1}{E_A} \cdot \frac{0.6}{(1-f_E)} \left[ \frac{d_P R_P}{6(1-f_E)S(D_A)_F} \right] \quad (37)$$

where

$$\frac{1}{E_A} \cdot \frac{R_P/(1-f_E)}{R_F/f_E}$$

has been utilized to replace  $1/D_A$ . An analogous form

$$\frac{(Ht_A)_{OF}}{d_P} = \frac{(Ht_A)_F}{d_P} + \frac{1}{E_A} \cdot \frac{(Ht_A)_P}{d_P} \quad (38)$$

can be obtained by multiplying Equation (20) by  $h/d_P$ . Upon comparison of the two forms, the factors affecting the individual transfer heights become readily apparent.

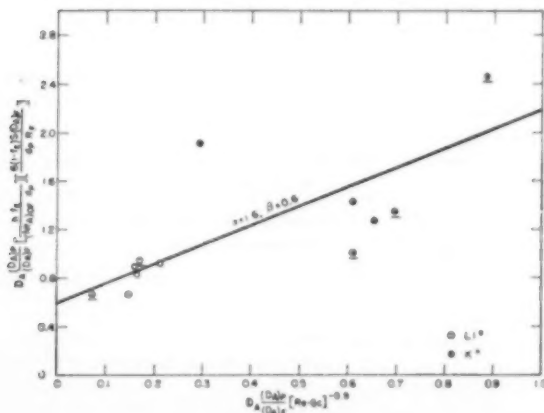


Fig. 16. Linear-correlation plot.

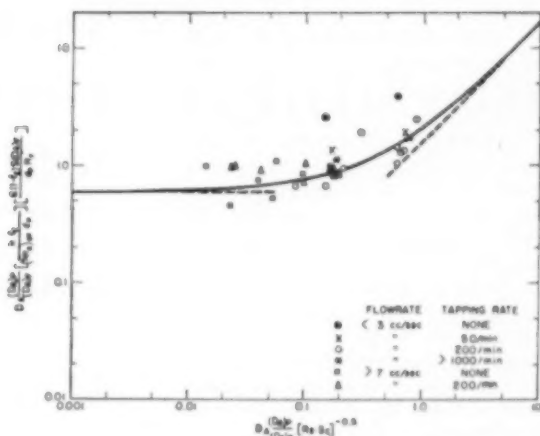


Fig. 17. Logarithmic-correlation plot.

Because of the limitations in the experimental equipment and analytical techniques, it was difficult to obtain results which fell definitely in either the internal or external diffusion-controlled area. For this reason it should be emphasized that the constants given in the foregoing relation are tentative, as the data do not cover a wide enough range of the abscissa to show that the relation would hold at the extremes of the indicated curve. More confidence may be placed on the 0.6 value for  $\beta$  than the other constants, because, as may be seen from Figure 16, any reasonable adjustment of the curve will not greatly affect the intercept.

In an attempt to extend the range of the data, and perhaps to obtain better contact between the resin and solution, two other means of contact within the column were evaluated: first, by free fall of the resin and, second, with a stirred contactor insert. Very little success was achieved with either because of difficulties in accurately assessing numbers of transfer units, void fractions, and (for the stirred contactor) Reynolds numbers. These aspects of the program are described in more detail in Appendices B (free fall) and C (stirred contactor).\*

#### Discussion of Results

At the low solution flow rates ( $< 3$  c.c./sec.) the tapped-screen unit was most effective in promoting good resin-solution contact, i.e., in reducing channeling. This will be observed by comparing the greater transfer heights of Run 1, which was made without the tapped screen (solid circles in Figure 17), with the others in this range, which involved tapping. On the other hand, there was no significant effect on

\* See footnote on page 139.

the results when the tapping frequency was varied between 50 and about 1,000/min.

With further reference to Figure 17, it is obvious that at the higher flow rates ( $>7$  c.c./sec.) the tapped-screen assembly offered no advantage. Apparently, under high flow-rate conditions, the greater turbulence not only reduced the fluid film resistance as anticipated, but also decreased channeling as much as did the tapped screens. Since the higher flow rates are of more commercial interest, it is advantageous that good contact can be obtained without the tapped-screen unit and its attendant mechanical complexities.

It will be noted that the difference between the  $\alpha$  and  $\beta$  values for the fixed- and moving-bed correlation relations indicates a displacement between the two curves. This is attributed to a difference in the contact efficiencies, the fixed bed having the greater efficiency. The factors contributing to this contact efficiency have not been established, but they may be related to differences between upflow and downflow, to the column-diameter-particle-diameter ratio, to the Reynolds number, and for the current study to the tapping frequency of the screen assembly.

Some of these factors were studied qualitatively in a short series of fixed-bed runs made at low flow rates. Here, upflow was less efficient than downflow, but the tapped screen increased the upflow efficiency. A column of smaller diameter was found to be more effective than one of large diameter. More details concerning these fixed-bed runs are given in Appendix D.\*

#### Acknowledgment

The authors wish to express their appreciation for the invaluable technical advice of Theodore Vermeulen of the University of California, of Edward R. Tompkins of the Naval Radiological Defense Laboratory, and of Jack J. Gordon of Stanford Research Institute. Portions of the experimental work were conducted by Raymond K. Cohen and Lydia Peters of the Institute, and their assistance is gratefully acknowledged.

#### Notation

$a$  = effective transfer area of film, sq. cm./c.c. of contacting zone.

$A, B, G$  = trace components A, B and gross component G.

$\delta$  = effective thickness of resistance film, cm.

$c_2$  = total ionic level in the solution phase, meq./c.c., equal to the

sum of the ionic concentrations of components A, B, and G.<sup>†</sup>

$d_p$  = mean diameter of resin particles, cm.

$D$  = distribution or partition parameter, dimensionless.

$D$  = effective ionic diffusivity for a trace component diffusing against the carrier component, sq. cm./sec.

$E$  = ratio of the slope of the equilibrium line to the slope of the operating line, dimensionless.

$f_E$  = ratio of void space outside resin particles to total volume of contacting zone, dimensionless.

$Ht$  = height of contact zone equivalent to a transfer unit, cm.; given by relation  $Ht = h/Nt$ .

$h$  = height of the contacting zone, cm.

$k$  = mass-transfer coefficient, cm./sec.

$K$  = generalized transfer coefficient, reciprocal sec.

$K$  = chemical equilibrium constant for exchange, dimensionless.

$M$  = slope of the equilibrium line, dimensionless.

$N_C$  = number of equilibrium contacts.

$Nt$  = number of transfer units.

$Pe'$  = Peclet prime number for the fluid,  $Pe' = Re \cdot Sc$ .

$Q$  = total ionic concentration of resin or ultimate capacity, meq./g. oven-dried resin.

$r_a$  = hydraulic radius, cm.

$R$  = volumetric flow rate, c.c./sec.

$Re$  = Reynolds number for the fluid.

$s$  = number of fixed-bed transfer units.

$S$  = cross-sectional area of column, sq. cm.

$Sc$  = Schmidt number for the fluid.

$u$  = point velocity, cm./sec.

$x$  = equivalent fraction of a component in solution with respect to the total ionic level of the solution, dimensionless.

$x^*$  = equivalent fraction in the solution in equilibrium with a given equivalent fraction on the resin, dimensionless,  $x^* = y/M$ .

$y$  = equivalent fraction of a component on the resin with respect to the total capacity of the resin, dimensionless.

$y^*$  = equivalent fraction on the resin in equilibrium with a given equivalent fraction in the solution, dimensionless.

<sup>†</sup>  $c_2$  is equivalent to  $C_2$  in reference (7) and to  $c_0$  in reference (12).

lent fraction in the solution, dimensionless,  $y^* = x \cdot M$ .

$\gamma$  = degree of approach to equilibrium transfer for a component, dimensionless.

$\mu$  = viscosity of the solution, poise.

$\rho$  = specific gravity of the solution, g./c.c.

$\rho_r$  = density of resin, g. oven-dried resin/c.c. true resin volume saturated with carrier component.

$\tau$  = residence time in contacting zone, sec.

#### SUBSCRIPTS

$A, B, G$  = components A, B, and G.

$entr$  = feed composition.

$exit$  = effluent composition.

$F$  = fluid (or solution) phase.

$i$  = interface values.

$OF$  = over-all value based on the fluid film.

$P$  = particle (or resin) phase.

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Presented at the A.I.Ch.E. Cleveland Meeting.

\* See footnote on page 139.

The importance of pilot-scale distillation facilities in petroleum and petrochemical research is manifold. Such equipment is used to obtain design and operating data for commercial installations, to perform distillations for other research programs, and in fundamental studies of fractionation (7).

Pilot-plant activities in Standard Oil Laboratories require distillation of batches of material ranging from a few gallons to a hundred barrels. Equipment is needed for preparing feed stocks, analyzing such feeds and products, finishing laboratory batches of chemical products for customer evaluation, and preparing high-purity materials for further study. Facilities are also needed for investigating developments in distillation techniques and equipment.

To meet these needs seven batch fractionating units have been installed in a new building designed solely for distillation work. The units range in boiler capacity from 2.5 gal. to 12 bbl. and have packed columns 1 to 10 in. in diam. They can be operated over a wide range of temperatures and pressures and are instrumented to permit close control.

#### Building and Utilities

The distillation building measures 77 room 43 by 62 ft. and 40 ft. high with struction. Figure 1 shows the exterior and Figure 2 the plot plan. A corridor separates the one-story office-laboratory wing from the process area. A covered loading dock adjoins the process area.

In the office-laboratory wing are hot and cold rooms, a utility room, and a locker-room. The hot and cold rooms provide for the storage of feed stocks and products at controlled temperatures from 34° to 200° F. Both are equipped with automatic carbon dioxide fire-fighting equipment.

The process area is a completely open room 43 by 62 ft. and 40 ft. high with a precast concrete roof that eliminates interior supporting columns. The concrete floor is divided into pitched bays. A trapped floor drain in the center of each bay empties into a closed sewer system.

A self-supporting steel structure with three levels above the ground floor has been installed in the process area. Stairways and ladders on two sides provide access to all levels. From the top level, a walkway leads outdoors to an escape ladder. Supported from the roof beams, monorails with manually operated chain hoists facilitate handling large equipment at any level. A dumbwaiter incorporated in the steel structure handles smaller items.

Utilities enter the process area from an exterior overhead utility bridge or from underground service lines. They are distributed by main headers on two

## A Laboratory for Pilot-Scale Distillation

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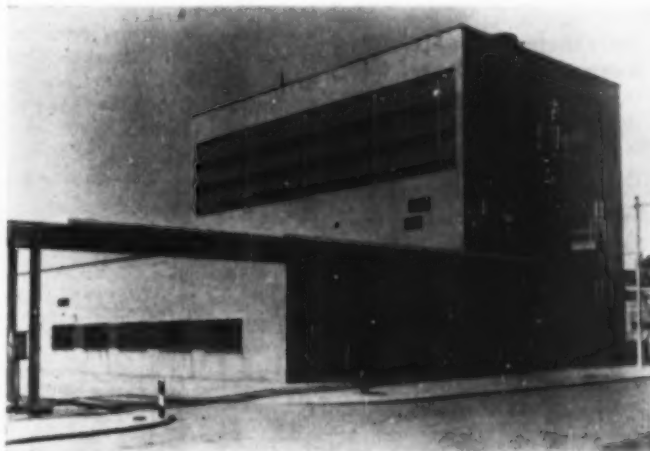


Fig. 1. Distillation building.

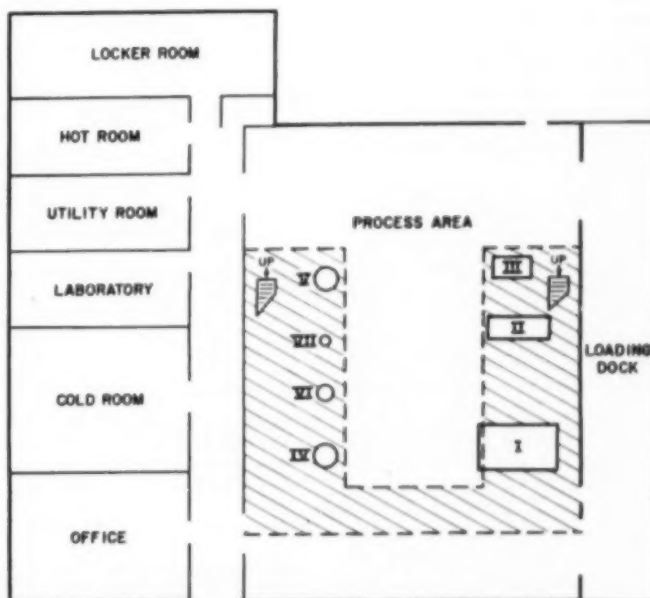


Fig. 2. Plot plan of distillation building.

opposite walls. A small steam-driven compressor provides air for emergency operation of instruments. The building has two vacuum systems: a three-stage steam-jet ejector with a capacity of 11.8 lb. of air/hr. at 5 mm. of Hg, and a mechanical pump with a capacity of 17 cu.ft./min. at 1 mm. of Hg. These two systems can be operated in tandem, the vacuum pump discharging into the intake side of the ejector.

A forced-air ventilating system supplies eight air changes per hour under normal conditions and sixteen in case of emergency. The building ventilation maintains the corridor at a slightly higher pressure than the process area to preclude the flow of vapors to the corridor.

### Process Equipment

Seven distillation units are described in Table 1. The three larger units are on one side of the process area and are similar in construction, as are the four smaller ones on the opposite side. All seven are designed for temperatures up to 650° F. at pressures from 1 mm. of Hg to 165 lb./sq.in.gauge. The boilers, columns, condensers, and product receivers are made of Type 316 stainless steel, heat treated and stress relieved.

To provide the desired low holdup and high efficiency and to facilitate packing changes, all columns contain dumped rather than oriented packing or plates. McMahon quarter-inch stainless-steel wire-gauze saddles (2, 3, 5), are used in most of the columns. In the two smallest columns, Fenske  $\frac{3}{32}$ -in. stainless-steel helices (1) give a better ratio of column diameter to packing size. In the 12 bbl. unit, Berl half-inch porcelain saddles permit distilling heavy stocks.

Blowdown tanks with internal water sprays are installed for emergency use. Each tank serves one or more units through a common header and has a gas vent through the roof of the building. Liquid accumulating in the tanks discharges through trapped outlets leading directly to closed underground sewers.

### LARGE DISTILLATION UNITS

Unit II is typical of the three larger units and is diagrammed in Figure 3. The boiler is heated by electrical strip heaters enclosed in air-purged sheet-metal jackets. The purge prevents accumulation of hydrocarbon vapors. An internal coil cools the bottoms. A vent line with a rupture disc and spring-loaded relief valve in series leads to the blow-down line. The rupture disc relieves abnormally high pressures in the system, and the relief valve prevents complete discharge of the contents of the unit to the blowdown. A spare nozzle on the top of the boiler permits installing a condenser for simple distillation. Thermocouples in the boiler measure the temperature of both the liquid and the vapor phases.

The column comprises five sections packed with McMahon wire-gauze saddles to a total height of 22.5 ft. The sections are flanged, the flange faces having small tongue-and-groove joints. Flat wire-mesh supports to retain the packing are fixed to the column wall by set screws. A short section between the column and boiler contains Berl saddles to reduce liquid entrainment. Removable sheet-metal jackets, containing insulation and tubular heaters, surround the column sections. Thermocouples are fastened to the column wall and to the adjacent interior surface of the jacket. The annular space between the jacket and column wall is purged with air.

Distributors between the column sections carry thermocouple wells and pressure taps that permit measuring the differential pressures across individual sections. Plan and cross-sectional views of a typical distributor are shown in Figure 4. The different heights of downcomers A and B and of weirs C

in the vapor risers accommodate wide variations in reflux rate.

The condenser is of the shell-and-U-tube type with cooling water inside the tubes and condensing vapors outside. It is vented through a surge tank and a pressure-control valve. The reflux collector below the condenser is a trapout tray. Total condensate is split into product and reflux streams, measured by rotameters. The reflux returns to the column on the top distributor plate. The product passes through a water-jacketed cooler and collects at ground level in two parallel receivers. Each receiver is surrounded by a jacket open at the top. A coil in the annular space between the jacket and the vessel permits either heating or cooling the product with a suitable fluid. The receivers are connected to vacuum, compressed air, and nitrogen.

The three large units are supported at ground level. A sliding guide at the condenser level accommodates upward expansion; a counterbalance relieves the boiler of the weight of the column and condenser. The boilers of these units are shown in Figure 5, and the condensers in Figure 6.

### SMALL DISTILLATION UNITS

Unit VI is typical of the four smaller units and is diagrammed in Figure 7. The boiler has an air-purged jacket

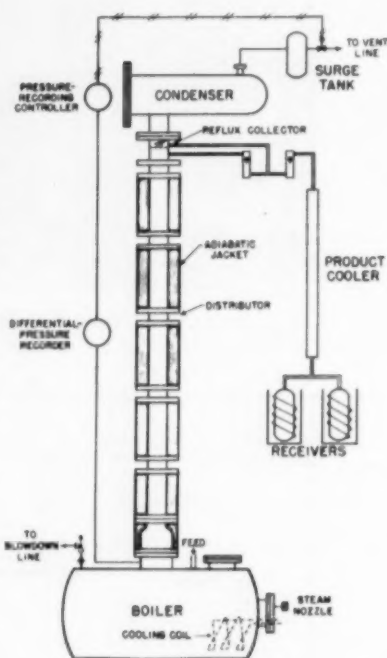


Fig. 3. Diagram of unit 11.

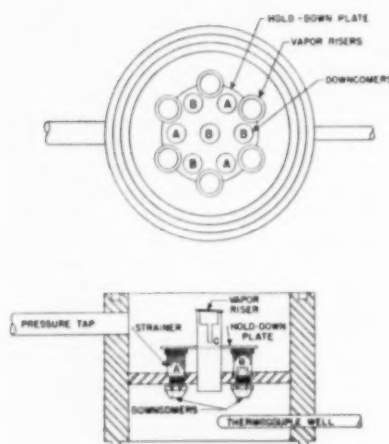


Fig. 4. Typical distributor.

Table 1.—Distillation Equipment

UNIT	I	II	III	IV	V	VI	VII
Boiler Capacity	12 bbl.	4 bbl.	1 bbl.	20 gal.	20 gal.	5 gal.	2.5 gal.
Boiler heating capacity, kw.	90	25	11.5	6.6	6.6	2.6	1.0
Column diameter, in.	10	6	4	3	2	1.5	1
Number of packed sections	4	5	3	1	3	3	3
Packed height, ft.	20	22.5	24	7	28.5	28.5	30
Packing material	Berl Saddles	McMahon Saddles				Fenske Helices	
Jacket heating capacity, kw.	14.7	13.1	9.6	3.0	10.4	10.4	2.7
Condenser surface, sq.ft.	150	43	20	12	12	13.8	2.2
Type of condenser	Horizontal	Shell-and-U-Tube				Vertical Bayonet	



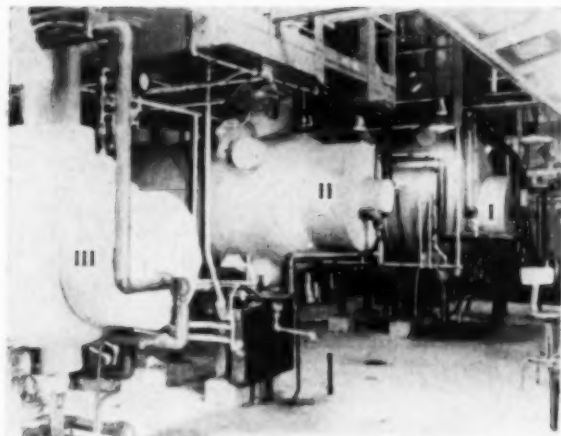


Fig. 5. Boilers of large distillation units.



Fig. 6. Condensers of large distillation units.

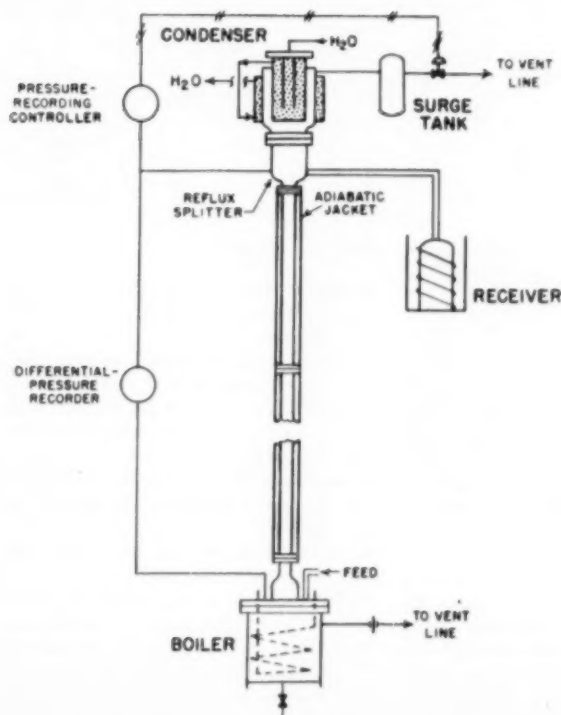


Fig. 7. Diagram of unit VI.

and also carries thermocouples, electrical heaters, and an internal cooling coil. The vent from the boiler to the blowdown line has a rupture disc but no relief valve, because the relatively small charge would not overload the blowdown system.

The column consists of three packed sections above a short de-entrainment section. It has no distributor plates. Wire-mesh cones support the packing. The condenser is of the vertical-bayonet type. Reflux and product are separated by a magnetic swinging-funnel splitter governed by a time-cycle controller (4).

Because of the small amounts of product obtained at high efficiency, holdup in the product lines must be minimized. Large holdups would cause excessive losses of product and prevent sharp separation of fractions. For this reason the four units have the receivers close to the condensers. The receivers are like those on Unit II, but only one is provided for each unit.

These four units are suspended from the roof supports. Sliding guides at the boiler level take care of expansion. The boilers of three of these units are shown in Figure 8, and the condensers of all four in Figure 9.

#### Instrumentation

Two instrument panels provide centralized control for the units. All instruments for the three large units are on a panel board on the ground floor. Those for the small ones are on a panel board on the top level, close to the product receivers. Both boards have the controls for each unit grouped together adjacent to the unit. A few instruments that serve more than one unit are in a central location on each board. Besides the process-control instruments, each board has gauges that indicate pressures in the utility headers.

#### TEMPERATURE MEASUREMENT AND CONTROL

Temperatures are obtained from indicators and recorders connected to the thermocouples on the units. The reflux heads on all columns are fitted with special resistance elements having an absolute accuracy within  $0.5^{\circ}\text{F}$ . These elements are connected to a recording dynalog that will measure temperatures from  $50^{\circ}$  to  $430^{\circ}\text{F}$ , with a precision of  $0.1^{\circ}\text{F}$ .

An adjustable transformer controls one set of strip heaters on each boiler—usually on the bottom surfaces. Switches energize the other heaters. Should any of the heaters on automatic control burn out, a transfer switch on the panel board allows new bands of heaters to be changed from switch control to transformer control. All columns are adiabatically jacketed. Thermo-

couples fastened to the column wall and to the inside of the jacket permit adiabatic operation. A separate adjustable transformer controls each section of the jacket.

Figure 10 outlines the arrangement of controls to the boiler and jacket heaters. Temperatures are controlled by manual adjustment of potentiometers located on the panel boards. These activate micro-relays to supply current to the motors of the adjustable transformers. The motor repositions the transformer, which varies the power supply to the heater. A meter with a multiple-position switch on the panel board indicates the voltages supplied to the boiler or jacket heaters. Because the transformers are not explosion-proof, they are located in the corridor outside the process area.

Columns III and V also have differential-pressure recorder-controllers (6), each connected to a pneumatically adjusted transformer that supplies power to selected boiler heaters. An increase in boilup rate from that desired leads to an increased pressure drop across the column. The recorder-controller responds to this increase and activates the transformer to reduce the power to the heaters.

#### PRESSURE MEASUREMENT AND CONTROL

Each unit has an absolute-pressure manometer, a differential-pressure recorder, and a pressure-recording controller that operates the valve in the condenser vent line. On five of the columns, the pressure-recording controller has a specially devised adjustable range chamber to give closer control at any point between 0 and 2000 mm. of Hg. The chamber consists of a sliding block containing mercury and connected to a constant-reference vacuum. The block holds enough mercury to span the 40-mm. pressure range of the instrument chart. For pressures greater than 2000 mm., the recorder is disconnected from the range chamber and linked to a Bourdon tube. Since these devices were designed and installed, other instruments performing the same service and occupying less space have become commercially available.

A nitrogen-bleed system introduces about 1 cu.ft./min. of gas into each column. This provides a constant flow of inert gas for the pressure-control valve in the condenser vent line to function against.

When more than one unit is operating under vacuum, the steam ejector is run at full capacity and sufficient air is introduced into the main header to maintain a slightly greater vacuum

Fig. 8. Boilers of small distillation units.

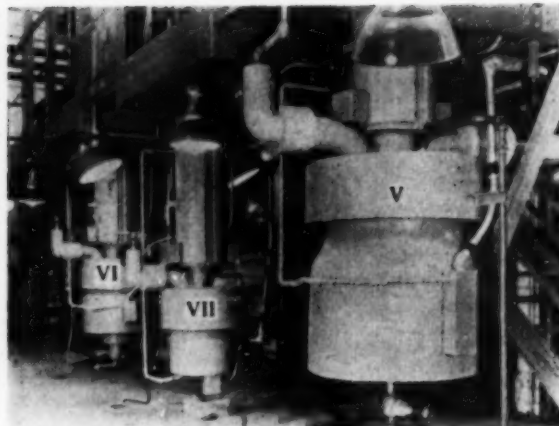


Fig. 9. Condensers and controls for small distillation units.

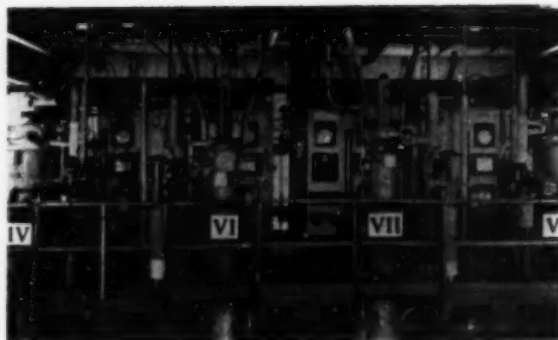
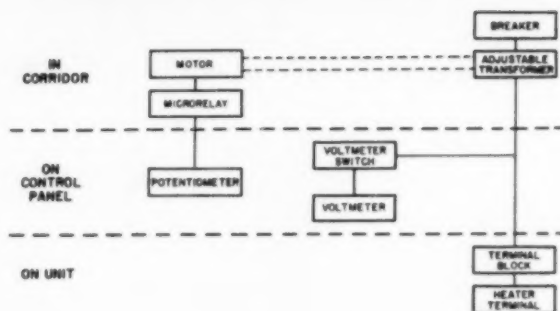


Fig. 10. Arrangement of heater controls.



than is required for the column operating at the lowest pressure. The entering air is regulated automatically by a pressure-recording controller operating a pneumatic valve. The pressure in the main header is the base point for the pressure-recording controller. The vacuum pump can be used in the same manner as the steam ejector, but it has a lower capacity and is intended primarily for use with the smaller columns.

#### Conclusions

Installation of these facilities was completed in 1952. Shake-down runs have proved the equipment to be operable. Plate-efficiency tests are planned for the near future.

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# A Survey of Gauges

## for Measurement of Low Absolute Gas Pressures

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Gauges for the measurement of gas pressures in the range from 760 to  $10^{-7}$  mm. Hg are discussed, with particular emphasis on those gauges of greatest present or potential usefulness in engineering applications. The gauges are classified according to the similarity of their operating principles. Attention is directed to the fact that various gauges measure different variables or combination of variables. Some gauges truly measure pressure (force per unit area), but others measure the number of molecules per unit volume, weighted differently for different gases. Advantageous and disadvantageous consequences of this fact are pointed out. Various new developments are described, some of potential immediate importance and others of interest principally for their ingenuity and novelty of approach.

Many excellent reviews of this subject have appeared from time to time. Why, therefore, is another such survey desirable? First, since certain of these earlier surveys place their major emphasis on one-of-a-kind research models, it seems appropriate to make available a summary emphasizing the properties of commercially available gauges which have been extensively used or may be expected to be widely used soon. Second, it seems well to emphasize which physical quantities the various classes of gauges do measure and which they do not, for although all are commonly spoken of as "pressure gauges" their indications may be influenced by other parameters such as gas temperature and gas composition. An awareness of the facts involved prevents improper application and misinterpretations and can, moreover, lead to useful techniques for measuring quantities such as temperature, density, and composition ratios. Finally, although various important methods of measuring low pressures are more than a hundred years old, the techniques are still developing, and some of the more interesting and important new developments are well worth summarizing.

The measurement of pressure, or closely related variables, in the range

below the atmospheric pressure of 760 mm. Hg will be considered. In accordance with scientific and engineering usage, pressures will be stated in mm. Hg reckoned from zero pressure rather than atmospheric. (With this understanding the use of the term "absolute pressure," which in certain important instances is ambiguous, will be avoided.) For pressures between about 0.001 and 0.000001 atm. values are commonly expressed alternatively in millimeters or in microns, a micron being a millionth of a meter or a thousandth of a millimeter. Pressures higher and lower than this range should always be (and nearly always are) expressed in terms of millimeters.

### Useful Operating Ranges of Various Measurement Principles

In a comparison of the many instruments concerned classifications both on the basis of operating pressure range and on the basis of general physical principles of operation are useful. Classification on the basis of pressure range will be considered first, although, as will be seen, a few instruments with very wide ranges are exceptions to this classification scheme.

Figure 1 gives in a rather condensed

fashion the ranges of pressure over which the various physical principles of operation are most useful. It should be emphasized that any single instrument of a given type (for example, an aneroid bellows gauge) will not necessarily cover the entire range indicated in Figure 1. Several different units of the same general construction may be required to span the complete pressure range indicated as being useful for the operating principle in question. Ranges of individual commercially available gauges will be given later in Figure 9.

### Gauges Based on Mechanical Force

Starting from 760 mm., lower decade (factors of ten) ranges of pressure, as indicated in Figure 1, will be considered. Gauges based on mechanical force are useful for the first few decades: Bourdon tubes, aneroid bellows, liquid manometers, and diaphragm gauges. These gauges, which are continuously indicating, are often used as circular-chart recording gauges. In the first three of these gauges a mechanical deflection is visually observed, either directly or, more usually, indirectly, with the aid of an amplifying mechanical linkage.

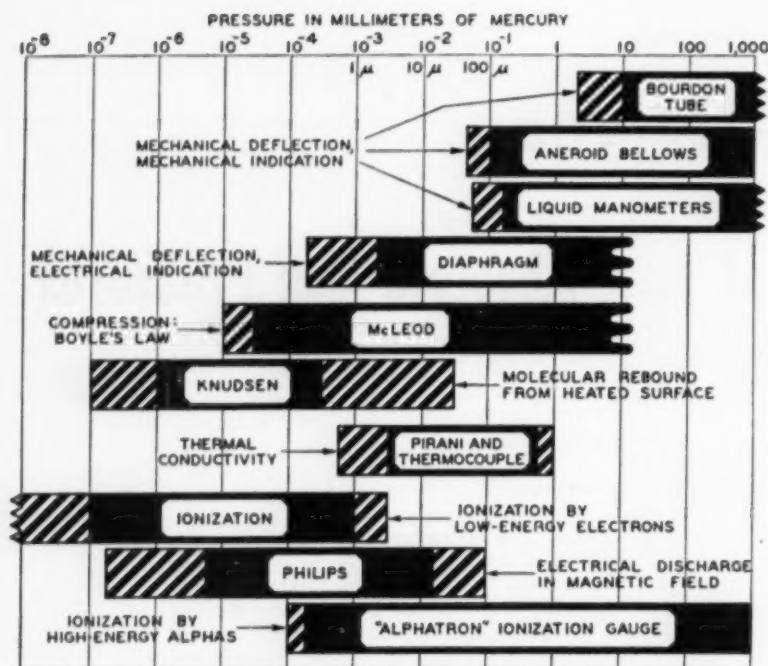


Fig. 1. Useful pressure ranges for various operating principles.

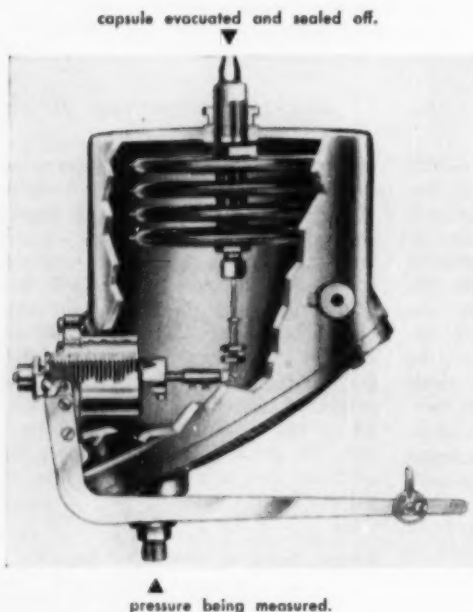


Fig. 2. Sensitive aneroid capsule element.

As indicated by the four-point jagged edge at the high-pressure end of the Bourdon tube and liquid manometer ranges, these instruments are also useful at pressures higher than those shown. The diagonally lined portion represents performance which, for one reason or another, is somewhat marginal. The other range-limit symbol—the three rounded fingers—represents roughly the limit beyond which it is not ordinarily worth while to extend

the particular operating principle, since another, simpler design is entirely adequate.

Figure 2 shows a commercial aneroid gauge of high sensitivity. The main bellows are evacuated and the unknown pressure is introduced into the surrounding chamber. High pressures collapse the bellows, which are thus self-protecting. The small metal bellows act as a vacuum-tight, friction-free fulcrum.

As Figure 1 shows, the principle of mechanical deflection visually observed is useful only above  $100\mu$ ; its greatest usefulness is above 1 mm. Extension to lower pressures is made possible by observing the mechanical deflection with more subtle and sensitive means, as in the diaphragm gauge. In two well-known commercial diaphragm gauges with ranges extending to slightly below  $1\mu$ , different electrical deflection-sensing means are used. One is based on the unbalance of a capacity-measuring alternating-current bridge circuit, and the other uses the variation of coupling between two tiny coils when the nearby metal diaphragm is deflected by the unknown pressure. In the former the deflection is brought back to null by an ingenious electrostatic attraction method, the unknown pressure being calculated from its proportionality to the square of the attracting voltage. This gauge has been widely used on mass spectrometer equipment.

As diaphragm gauges are made more sensitive, they become subject to a host of ills, which are all significant limitations: mechanical fatigue and hysteresis, susceptibility to ambient temperature changes and differential temperatures, vibration and orientation sensitivity. Accordingly, when gauges for measuring pressures lower than a few hundred microns are devised, some desirable feature must almost inevitably be relinquished.

#### Medium- and Low-Pressure Gauges, Nearly Composition Independent

The McLeod and Knudsen gauges most nearly retain the feature of composition independence. Figure 3 shows two forms of the McLeod gauge, which may be termed a pressure-multiplying liquid manometer. Direct visual measurement of low pressures is obtained by compressing a known large volume of gas into a much smaller known volume; the pressure exerted by this compressed gas is then sufficient to support a measurable column of the manometric fluid, which is nearly always mercury. It is necessary that the gas obey Boyle's law, hence condensable vapors generally cannot be measured accurately with McLeod gauges of the usual compression ratios. The continuous-reading feature is also sacrificed: manipulation is somewhat awkward and about a minute is required for pressure equalization and reading. Vapors of the mercury or other manometric fluid will diffuse into the vacuum system and may cause trouble unless valves or cold traps are used. Despite these shortcomings the McLeod gauge is, however, a fundamental standard of pressure, and



it is widely used by manufacturers in calibrating other more convenient gauges.

As Figure 1 shows, a Knudsen gauge is useful in a pressure range which overlaps that of the McLeod gauge nicely and extends to pressures about two decades lower. Many variations in construction have been made from time to time but the only commercially available Knudsen gauges have the general construction shown schematically in Figure 4. A very light vane and a mirror are supported on a delicate torsion suspension. Adjacent to the suspended vane there are two fixed vanes heated electrically. When very rarefied gas is present in the regions between the vanes, a force is experienced whereby the suspended vane is repelled against the torsion of its suspension. The resulting deflection is read on the translucent scale, and the pressure obtained from a calibration curve.

For proper operation of the Knudsen gauge, it is necessary that the mean free path of the gas molecules be large, which implies pressures well below a micron: the mean free path in inches is very roughly equal to 2 divided by the pressure in microns of mercury.

If the gas pressure is sufficiently low so that the mean free path is much greater than the gap between vanes, then the angular displacement of the vane, read on the translucent scale, is accurately proportional to the pressure of the gas present. If the construction of the gauge is such as to establish definite temperatures for the various elements, then within a few per cent the deflection is essentially independent of the nature of the gas, including condensable vapors, as long as the above mean free path criterion is met. No commercial gauge known to the author embodies this rather expensive construction, however, and the feature of approximate composition independence is thus usually confined to the lower portion of the pressure range. Despite its interesting potentialities, the Knudsen gauge in its present available form has seen but little continuing industrial application. The most significant reasons for this neglect are probably a tendency toward mechanical awkwardness and the lack of convenient remote indication. An interesting Knudsen gauge without some of these limitations has recently been described by Litting and Taylor.

#### Thermal Conductivity Gauges

As Figure 1 shows three more types of gauges are useful in the range of pressures above a micron. The thermal conductivity gauges—Pirani gauges

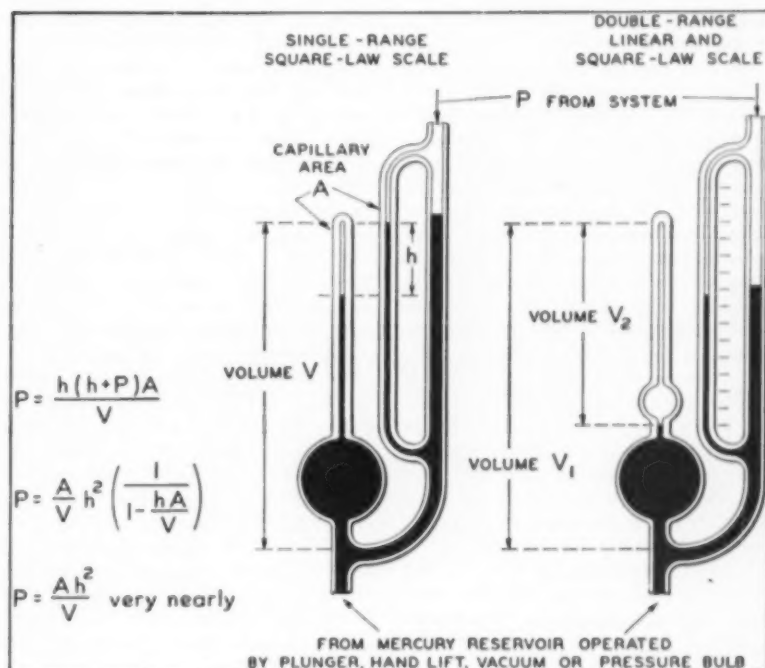


Fig. 3. McLeod gauges.

and thermocouple gauges—which are extremely simple and inexpensive, are widely used in the range from a few microns to a few hundred microns. The important element of these gauges is a fine wire or ribbon heated electrically and immersed in the gas whose pressure is to be measured. The steady-state temperature attained by this heated wire is determined by a heat balance: heat loss takes place by conduction through the electrical connecting leads, by thermal radiation, and, convection being unimportant, by conduction

through the surrounding gas. It is a well-known and highly interesting fact that for pressures within two or three decades of atmospheric, the heat conductivity of gases is very nearly pressure independent. This curious state of affairs is a result of the fact that for these pressures the mean free path of a gas molecule is very much smaller than the dimensions of ordinary apparatus. For pressures low enough so that the mean free path is not negligibly small, however, the thermal conductivity changes with pressure and even-

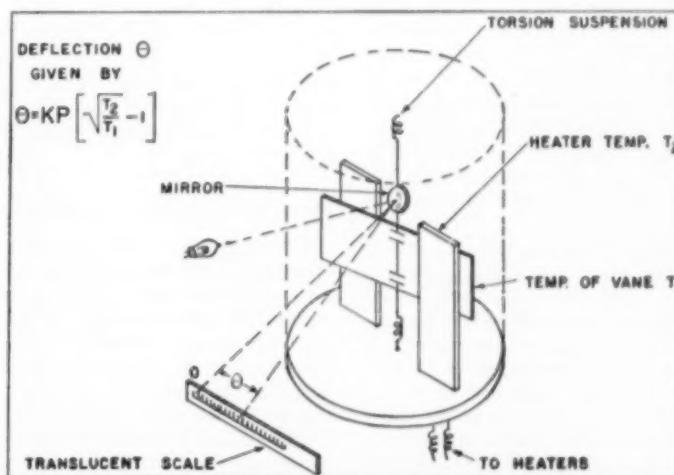


Fig. 4. Knudsen gauge.

tually decreases in linear proportion to the decreasing pressure.

The relationship between wire temperature and gas pressure is thus characteristically different in three different ranges of pressure. At high pressures (above 1 mm.) the constant gas conduction accounts for nearly all of the heat loss, and the relatively low temperature attained by the wire is independent of pressure. At intermediate pressures the heat loss through the gas decreases as discussed above, and all three mechanisms of heat loss are important, with the result that the attained temperature rises and depends on the pressure. At pressures below a few tenths of a micron the heat loss through the gas is negligible compared with conduction through the leads and with radiation: the temperature tends toward a flat maximum and again becomes independent of pressure.

In the Pirani gauge the wire element is usually made one of the four electrical resistances of a Wheatstone bridge; a change in pressure alters the

following the standard pressure calibration with reasonable accuracy.

Since the relation between gas pressure and wire temperature depends on cooling by the gas and since different gases have somewhat different heat conductivities, the calibration curve of the gauge is different for different gases. Furthermore, the indications at low pressures depend on the surface condition of the wire, which can affect both the heat radiation (emissivity) and the heat conduction through the gas (accommodation coefficient). The thermocouple gauge, in particular, is rather unreliable for pressures below about 20  $\mu$ . Except in specialized designs not readily available commercially, these gauges do not follow rapid fluctuation in pressure very satisfactorily since an appreciable time (generally greater than one second) is required for the necessary heating or cooling to take place and for the final reading to be attained. Despite these limitations Pirani and thermocouple gauges are so simple, inexpensive, and

equal. Furthermore, the quantity actually measured is not pressure but number of gas molecules per unit volume; the molecular velocity (and hence the temperature) has no effect on the ionizing process. This fundamental difference is of great importance and great potential usefulness, since gauges operating on the ionization principle can measure gas density directly. Space does not permit discussion of this point, but with ingenious application the ionization technique, suitably combined with other techniques for measuring true pressure, temperature, sound velocity, and the like, is applicable to a wide variety of instrumentation problems.

Figure 5 shows the common hot-filament ionization gauge, wherein the ionizing agent is a stream of low-energy electrons emitted from an incandescent filament. The electrons are attracted toward a grid, which is at a positive potential with respect to the filament and which may take the form of a spiral as shown in the figure. Surrounding the filament and grid structure is a cylindrical electrode which is maintained negative with respect to the filament and which serves as collector for the positive ions formed in the gap. Most of the electrons miss the grid at first approach and oscillate a few times in the space between the ion collector and the filament before ultimately reaching the grid. While traversing this path they make ionizing collisions with intervening gas molecules; those positive ions formed in the space between the grid and the collecting electrode are attracted to the collector and this ion current is then measured.

The dimensions of the gauge, most particularly the outer cylindrical collector, determine the sensitivity of the gauge, which may be expressed as the ratio of ion current to electron current, for a particular gas (usually dry air) at a stated pressure (usually a micron). Equivalently, sensitivity may be expressed as the ratio of ion current to gas pressure, for a particular grid electron current. A typical sensitivity is 100  $\mu\text{a}/\mu$  of air pressure at 5 ma of grid current.

The hot-filament ionization gauge suffers from various disadvantages. Since the electron-emitting materials are operated at red or white heat, they are drastically affected if the gas pressure is inadvertently increased above a few microns. Without protective circuits burnout is inevitable if such a gauge is exposed to atmospheric pressure with the filament hot. Protective circuits are in common use to relieve this disadvantage, but a shortening of life at operating pressures above a micron establishes this figure as the

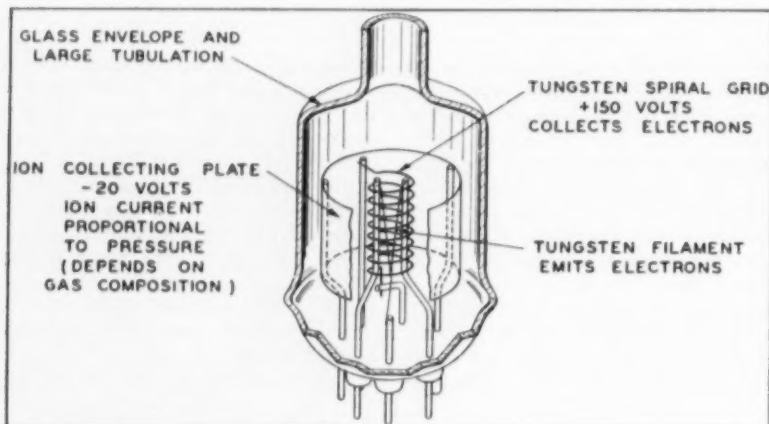


Fig. 5. Ionization gauge.

wire temperature and hence its resistance, thus unbalancing the bridge and resulting in a useful current in the bridge microammeter. As indicated in Figure 1, the most reliable range is from a few microns to a few hundred microns.

The thermocouple gauge is a simple alternative means for utilizing the relationship between wire temperature and pressure. One or more thermocouples, in thermal contact with the heated wire, are connected to a low-resistance microammeter bearing an appropriate nonlinear scale of pressure. It is customary to adjust the current input to the wire heater to some factory-determined value which will result in

easy to use that they are universally used where a pressure indication, rather than an accurate measurement, is all that is required.

#### Gauges Using Electrical Ionization

The operation of an important class of gauges involves ionizing the gas by some means and then measuring the ion current. By suitable design this ion current can usually be made to follow a linear law over several decades. It is important to recognize that the ionizing properties of various gases differ characteristically; thus the ion current for one gas will differ from that of another, even though their pressures are

upper limit to the useful pressure range. A further disadvantage is that the hot filament heats the gas drastically, which may cause objectionable chemical reactions to occur, to the detriment of the gas or the gauge. Finally, since the various portions of the gauges are at elevated temperatures, there is considerable difficulty with sorption and evolution of gas by the gauge itself, effects which can mask the desired response to the gas pressure being measured. At pressures below  $10^{-7}$  mm. a limitation due to the action of soft X-rays has been recognized and circumvented, but these pressures are not of interest in this study.

Some of these disadvantages are partially or wholly removed in the Philips gauge, invented by Penning. This is a cold-cathode gauge and consequently is free from the high temperature disadvantages of the hot-filament ionization gauge. Figure 6 shows schematically the construction of a typical Philips sensing head. The anode is an open-ended pill box and the cathodes are disks spaced coaxially a short distance from the ends of the anode. An electric potential of approximately 2000 v. is applied between anode and cathode, and the gauge elements are immersed in a longitudinal magnetic field of approximately 500 gauss, generally obtained from a permanent magnet. The function of the magnetic field is to force the electrons which appear in the inter-electrode space to travel in spiral paths of many turns. Thus, each electron traverses a long path before being collected at the anode and has a correspondingly good chance of producing ionization in the gas. This increased path length lowers the minimum pressure at which an electrical discharge can be self-sustained, and makes the Philips gauge useful at lower pressures than can be employed in other gas discharge devices.

The range and linearity of the Philips gauge are sensitive to the materials of construction and to the exact electrode configuration. One disadvantage is that there is a considerable tendency for the surface of the high-voltage insulator to become contaminated by the action of the discharge; this requires periodic cleaning of a drastic nature, such as sand blasting. The great advantage of the Philips gauge is that it is bernout proof and can stand exposure to atmospheric pressure without damage.

The third principal type of gauge operating on the ionization principle is the Alphatron ionization gauge, shown schematically in Figure 7. Here the ionization of the gas is produced by a constant flux of high-energy alpha

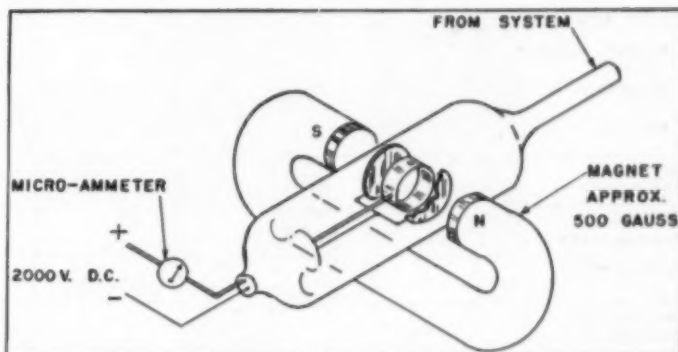


Fig. 6. Philips gauge sensing head.

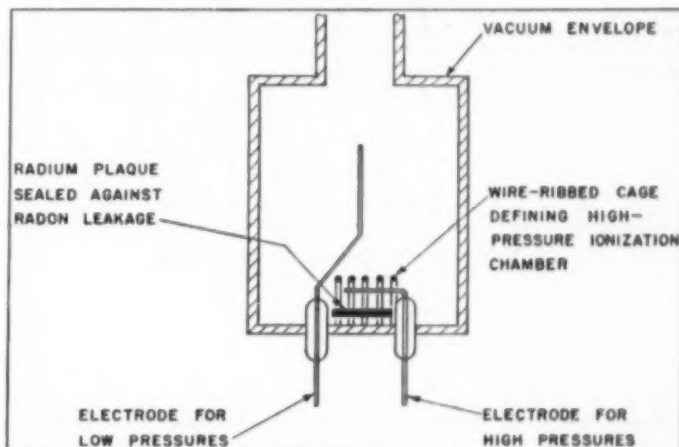


Fig. 7. Sketch of Alphatron ionization gauge chamber for six decade pressure range.

particles emitted from a thin foil containing radium and its radioactive decay products. The radium is sealed to prevent escape of radon, the only gaseous decay product, and the amount of radium required is small enough to be entirely nonhazardous.

The alpha particles are very effective ionizers of the gas inside the gas chamber. The ion current is, however, too small to be read directly on a microammeter and requires amplification by a simple circuit. This circuit is not shown in the sketch of Figure 7, but the connection to it is made by way of the insulated electrodes in the end of the ionization chamber. The Alphatron shares with the other electrically indicating instruments—the thermocouple, Pirani, Philips, and hot-filament ionization gauges—the advantage of a sensing head and an indication unit which are connected by means of a cable of noncritical length and which can hence be physically separated for maximum convenience.

The Alphatron has several uniquely useful features. First, since no parts of the gauge are required to operate at any temperature other than ambient temperature, there is a complete absence of the thermal effects which are

so troublesome in the hot-filament ionization gauge. This also makes it possible for the gauge to operate satisfactorily at any temperature from a few degrees above absolute zero to the melting point of the materials of construction. A second advantage is that no high-voltage discharge is used and there is consequently no "gettering" action from this cause. The third advantage is the inherent linear relationship between gas density and ion current, provided only that certain dimensional considerations are recognized in the design. By means of the ion-chamber configuration sketched in Figure 7, it has recently been found possible to make the range of a single instrument cover somewhat more than six factors of ten with perfect linearity.

#### Summary of the Characteristics of Commercial Gauges

Figure 8 is an attempt to summarize various properties of the gauges discussed in this paper. The pertinent properties have been phrased as questions stated in the left-hand column, the questions being put in such a way that a yes answer indicates a point in favor of the particular gauge. A blank



KEY TO SYMBOLS			BOURDON TUBE	ANEROID CAPSULE	DIAPHRAGM GAUGE	LIQUID MANOMETER	McLEOD	KNUDSEN	PIRANI AND THERMOCOUPLE	IONIZATION GAUGE	PHILIPS GAUGE	ALPHATRON <sup>®</sup> GAUGE
	SLIGHT TROUBLE											
	MODERATE											
	SEVERE											
COMPOSITION INDEPENDENT?												
LEAVES GAS UNCONTAMINATED?												
UNCONTAMINATED BY GAS?												
TEMPERATURE INDEPENDENT?												
USABLE AT LOW TEMP.?												
USABLE AT HIGH TEMP.?												
REMARKS												
	HIGH PRESSURE ONLY											
	RATHER DELICATE											
	VAPOR PRESSURE											
	GAS SOLUBILITY											
	NON CONDENSIBLE GASES ONLY											
	DELICATE TEMP. AFFECTS CALIB.											
	TEMP. AFFECTS CALIBRATION											
	HOT FILAMENT MAY INJURE GAS											
	SOME GETTING BY DISCHARGE											

Fig. 8. Properties of most important gauges.

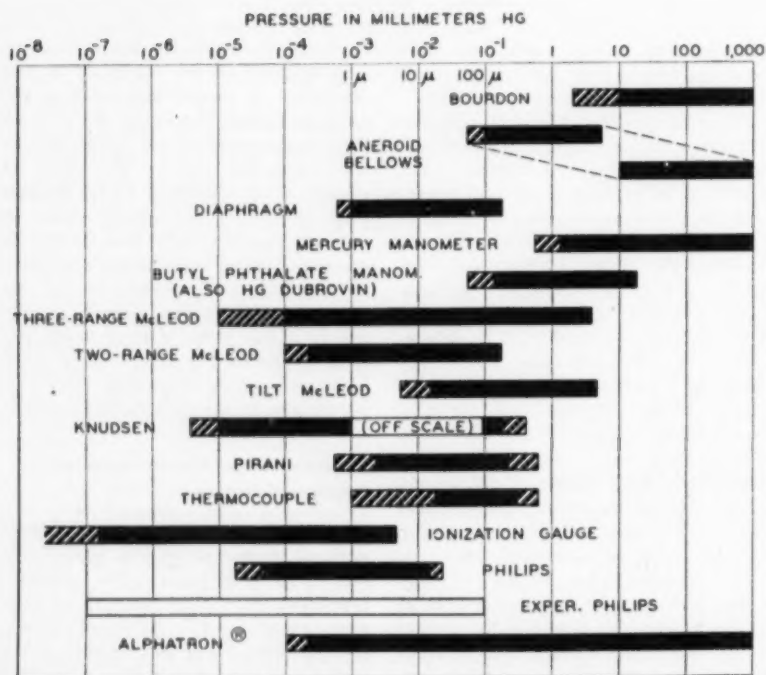


Fig. 9. Ranges of some commercially available gauges.

square indicates such a yes answer, and as shown in the key at the upper left-hand corner there are three degrees of no answers, represented by three degrees of diagonal shading. It is, of course, impossible to make the indicated evaluations completely quantitative, but Figure 8 has been carefully considered and should prove a useful guide and summary.

As mentioned earlier, the pressure ranges over which various operating principles are most useful were set forth in Figure 1, without the implication that a single unit embodying any particular operating principle would cover the entire range given. Figure 9 has been drawn so that an idea can be obtained of the useful range of individual units commercially available. It can be seen that the mechanical deflection gauges are generally single-range units covering pressure ranges of two, or at the most three, decades. McLeod gauges are available covering a five-decade range. The commercially available Knudsen gauge covers a low pressure range of about two decades; with increasing pressures above a micron the gauge reads off-scale until at high pressures this indication again becomes small enough to give an on-scale reading. This can be a serious disadvantage since a single reading thus can correspond to two widely different pressures.

The Pirani and thermocouple gauges are most useful over about two decades of pressure. In contradistinction, all three types of gauges based on the ionization principle—the hot-filament ionization gauge, the Philips cold-cathode gauge, and the Alphatron ionization gauge—have useful pressure ranges of many decades.

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Presented at A.I.Ch.E. French Lick meeting.



In recent years the cost of maintenance work in chemical plants has been increasing steadily. The increase has been very large, measured in dollars, but perhaps of more importance has been the fact that maintenance is becoming a larger factor in total manufacturing cost.

Two developments have contributed to this relative increase. One is that the chemical industry has made wide application of technological improvements to mechanize manufacturing processes and increase productivity. Equipment has been speeded to attain maximum possible output with closer tolerances of quality and maximum safety. Besides being more complicated and intricate, equipment has more instrumentation and other engineering advancements in design. As the engineer's dream of the automaton is approached, there are substantial decreases in the number of operators required, but at the same time the maintenance load is increased. In some new plants there are as many workers on maintenance as in operation. Thus, the technological advances which decreased operating labor increased maintenance cost.

Another important reason for increased maintenance cost is that maintenance work has not been subjected to the same intensive scrutiny and study as has production work. Many industrial engineering techniques have not seemed so readily applicable to maintenance, and often the importance of maintenance as a factor of cost was not recognized.

To reverse the trend of soaring maintenance cost, industrial engineering techniques must be applied to maintenance to the same degree that they are applied to production. In several plants of the du Pont Company, for instance, the use of techniques of measurement improved maintenance effectiveness.

#### Proper Methods

In order to insure effective performance, maintenance personnel must have proper methods, that is, they must know what to do, how to do it, when to do it, have the best tools to do it with, have all necessary materials on hand, and do the work under the most favorable conditions. Controls which aid in developing proper methods include:

1. Planning the job.
2. Scheduling the job.
3. Control of materials.
4. Control of tools.
5. Preventive maintenance.
6. Maintenance cost analysis.

**PLANNING THE JOB** requires an orderly procedure for authorizing work. It consists of an analysis of the job for: the work to be done, manpower requirements, material require-

ments, and tool requirements. A step-by-step procedure and safety precautions must be determined, and everyone concerned with the execution of the job must be informed of the plan. At this stage comparisons of alternate schemes for accomplishing the work often lead to fruitful improvements in methods.

**SCHEDULING THE JOB** includes determination of the time when the manpower and material will be available. Establishment of time for starting and completion is made in this step, and everyone concerned is informed.

**CONTROL OF MATERIALS** involves consideration of the technical and economic factors which determine the selection of the best material, arrangements to insure delivery at the job site of all material at the required time, and communication of material requirements to the stores or purchasing departments.

**CONTROL OF TOOLS** covers the selection of the proper tools for the method adopted and the materials selected and includes arrangements for delivery of these tools to the job when needed.

**PREVENTIVE MAINTENANCE** includes provision of a schedule for inspection, adjustment, and overhaul of each major piece of equipment

and analysis of all forced outages or failures in service which may indicate that a revision of this schedule is needed. Continuous review of the schedule is necessary to insure inspection and overhaul at economical intervals. An adequate knowledge of the history of equipment maintenance is a prerequisite to the foregoing.

**MAINTENANCE COST ANALYSIS** assumes the existence of an adequate maintenance cost system. It furnishes the basis for a comparison between alternate methods and provides a continuous check on maintenance performance or effectiveness, and resulting cost, which is the final answer.

The term *measurement* rather than *time study* is used in this discussion because *time study* generally implies only the determination of time values, and *measurement* covers the determination of time values and their application. Time study is no longer the only technique used for labor measurement; the new technique of predetermined time values for basic motions offers many advantages in setting time values. The Du Pont Company has used one of these, Methods-Time-Measurements for the measurement of certain types of maintenance work with considerable success.



Lyman A. Darling, author of the accompanying article with H. A. Bogle, is director of maintenance engineering, utilities engineering, and management engineering sections of the Engineering Service Division, Engineering Department, Du Pont Company, Wilmington, Delaware. His first employment was with the Commonwealth Edison Co. Later he engaged in power work in the refining department of the Texas Co. In 1926 he joined Du Pont at its Old Hickory, Tenn., rayon plant. Subsequently he became works engineer at Hanford.

The co-author of this article Hugh A. Bogle has been employed by the DuPont Company since he graduated from the University of Tennessee in 1929 with the degree of B.S. in chemical engineering. Currently he is serving as supervisor of planning and measurement of the maintenance engineering section. His first years with Du Pont were spent in research and production work and later on up to his recent appointment Mr. Bogle was engaged in industrial engineering assignments, and in consultant work in the Central Engineering Department.

## Productivity in Chemical Plant Maintenance

**Table 1.—Illustration of a Basic Data Time Value**

Operation—Install a ½-in. bolt

Description—Position self, insert bolt in hole, place nut, and tighten with a ratchet wrench

Normal Time Value—0.89 min./bolt

**Table 2.—Illustration of a Summary Value**

Operation—Make up a 2-in. flange joint

Description—Plan layout and measure job, dope and place gasket, dope and place 4½-in. bolts

Normal Time Value—	
Layout .....	5.0 min.
Dope and place gas. ....	0.5 min.
Dope bolts .....	1.0 min.
Place 4½-in. bolts .....	3.5 min.
Total .....	10.0 min.

JOB ANALYSIS SHEET				
JOB TITLE	RENEW PUMP LINE TO D-10 AND H-11		JOB NO.	CODE 100
LOCATION	BUILDING NO. 2		CRAFT	PIPE
ANALYZED BY	J.C. HERITAGE		DATE	AUGUST 3, 1953
OPERATION	UNIT	QUANTITY	NORMAL MINUTES	
			PER UNIT	TOTAL
TRAVEL	TRIP	2	8	16
PREPARATION AND CLEAN UP	MAN / DAY	2	10	20
CUT & THREAD 2" PIPE	PIECE	13	5.5	71.5
APPLY SCREW FLANGES	FLANGE	26	4.4	114.4
TRANSPORT TO JOB & RET. SCR	TRIP	2	12	24
BREAK 2" FLANGED JOINTS	JOINT	26	3.9	101.4
REMOVE 2" PIPE	FOOT	65	0.6	39
POSITION 2" PIPE	FOOT	65	1.1	71.5
POSITION 2" FLANGED FITTINGS	FITTING	11	1.3	14.3
MAKE UP 2" FLANGED JOINTS	JOINT	26	10.1	262.6

TOTAL	=	937.7
ALLOWANCE - 10 %	=	93.7
STANDARD MINUTES	=	921.4
STANDARD HOURS	=	15.4

Fig. 1.

The term *basic data* involves the proper description and determination of the normal time of an element or small portion of work commonly associated with a bodily motion or perhaps with the manipulation of a hand tool. Since basic data is so widely used in successful standards applications of direct labor, it follows that maintenance work also could be broken down into common and uniform elements of work. Since a basic-data element is repetitive in any class of work, nonrepetitive jobs could be measured by simply combining the required elements to arrive at standard time values. It was as a result of this basic reasoning that labor measurement was applied to maintenance work.

#### Requirement for Success

Successful application of measurement to maintenance work involves the following steps:

1. Development of elemental time values.
2. Development of summary time values or standards.
3. Job analysis and application of standards.

#### DEVELOPMENT OF ELEMENTAL TIME VALUES

By this is meant an element of work properly described and the normal time value determined. Table 1 shows an example of an element, namely, installing a ½-in. bolt. The operation includes positioning self, inserting bolt in hole, placing nut, and tightening with ratchet wrench. The normal time required to perform this operation without allowances is 0.89 min./bolt.

This approach was followed in determining the elements and time values applicable to each maintenance craft. The number of elements for an individual craft is large, but not so large as might be supposed. These elemental values can be used at any plant, regardless of the product. After a sufficient number of elemental values have been determined, further time studies are not required except for new types of work.

#### DEVELOPMENT OF SUMMARY STANDARDS

The elemental values are too small and occur in too great numbers in actual jobs to use in day-to-day application. It is necessary to develop summary stan-

dards by combining the elements into groups as they would normally be used. Table 2 shows an example of the formulation of a summary standard. Shown are the elements and the total time of 10.0 min. for making up a 2-in. flanged joint. Summary standards based on individual plant conditions and equipment must be assembled to fit an individual plant.

Like the number of elements for an individual craft, the number of elements for any plant is large; however the number of combinations for *application* standards for any one plant is not necessarily large. The summary standards required to measure all types of pipe work cover twenty pages, but seldom does a single pipe crew do all kinds of pipe work. All the summary standards regularly used by some craft groups can usually be reduced to one page, and many of the standards are soon memorized by those using them.

#### ANALYSIS AND APPLICATION

Measuring a job before beginning the work is advantageous. Measurement requires a thorough job of planning, which may be called preplanning. Preplanning and measurement should be done by an analyst thoroughly familiar with all the details of the craft. Usually a member of the craft group, he should have imagination, initiative, leadership, and craft knowledge. Often he is the potential foreman for that group.

When a work order for maintenance work is received, the analyst first discusses the job with the foremen of the crafts involved to find the best approach. A visit to the site of the job or a review of the work order with the originator may be necessary to determine the best methods and most effective equipment and the time for doing the job with a minimum of interference with operations. Figure 1 illustrates the kind of detail which is required.

The last two columns of Figure 1 are the time columns. In the first is shown the "Normal Time" value per unit of work. This is multiplied by the quantity of units for this particular job, and the result is shown in the total time column. The total of this column, along with a percentage allowance for fatigue and personal time for the workmen, is the total time allowance for the job, not the elapsed time. It is usually expressed in terms of hours. The actual percentage allowance may vary for plants, according to local custom and agreement. In some places this figure may have been established by experience with other measurement systems.

In order to insure that the benefits of the thorough and precise analysis involved in planning the job are transmitted intact to the mechanics and

other people directly concerned, an additional form, called a job summary sheet, Figure 2, is normally used. If there is an engineering drawing for the job, this Job Summary Sheet may be attached to the drawing for reference. If more than one craft were necessary to complete the work, sufficient information would be provided in the job description to assure coordination of the work of several crafts. This sheet represents the combined results of all the planning and analysis of the analyst, the foreman, and the originator of the request.

On this Job Summary Sheet, safety hazards are pointed out and safety precautions included in the description of the work to be performed. Time required to take these precautions is included in the time estimate.

A copy of this summary sheet should be sent to the stores department several days in advance of the starting date to prevent delays due to shortages of these items. Normally, the craft maintenance supervisor will not start his mechanics upon a job until he is certain that all materials are on hand.

### Summary

The advantages of a measurement program for plant maintenance work are the following:

1. A basis for development of improved methods.
2. Better work planning.
3. Control of maintenance forces.
4. A basis for budgeting available maintenance services according to the needs of various operating departments.
5. A definite improvement in worker morale due to avoiding delays and confusion. In every case where this technique has been used, there have been requests from mechanics that work not covered be included in preplanning and measurement.
6. Promotion of closer cooperation between maintenance and operating personnel. Where the operating people are convinced that the maintenance department is determined to provide better service, they will do much to cooperate.

The many intangible benefits derived from the use of an organized measurement program are difficult to evaluate in terms of dollars. It is relatively easy to determine the actual cost of maintenance services in a plant. It is not a simple matter, however, to evaluate the full effect of poor maintenance or lack of maintenance, as this shows up in high production costs from operating delays and lost production. But Measurement is not a cure for all maintenance ills. On the contrary, it introduces some problems and headaches that are peculiarly its own.

As a matter of fact, a maintenance department must be well organized and well run before it can possibly succeed with measurement. No maintenance group is ready to undertake measurement until it has the functions of planning and scheduling well established as a normal part of its operation. Measurement is a means of lifting these functions to a level of effectiveness higher than the levels achieved without measurement.

In spite of the difficulties, the use of the preanalysis and measurement technique in the du Pont Company has made possible significant improvements in the effectiveness of maintenance work. Figure 3 shows a comparison of effectiveness of maintenance labor before and after installation of preanalysis and measurement. A gross saving of about three dollars has been realized for every dollar expended in the application of the program.

*Presented at A.I.Ch.E. St. Louis meeting.*

JOB SUMMARY SHEET			
JOB TITLE		RENEW PUMP LINE TO K-10 AND K-11	JOB NO.
LOCATION		BUILDING NO. 2	CODE
ANALYZED BY		J.O. HERITAGE	DATE
		AUGUST 2, 1953	
JOB DESCRIPTION			
<p>PUMP LINE RUNS FROM P-10 ON FIRST FLOOR, SOUTH SIDE, BAY 2, TO K-10 AND K-11 ON SECOND FLOOR IN BAY 2.</p> <p>1. PROCURE MEASUREMENTS FOR NEW 8" LINE AND REQUEST OPERATION TO DRAIN LINE.</p> <p>2. FABRICATE NEW PIPE</p> <p>3. LOCK OUT &amp; TAG PUMP SWITCH</p> <p>4. REMOVE EXISTING LINE AND INSTALL NEW</p>			
MATERIAL			
AMT	DESCRIPTION	AMT	DESCRIPTION
100'	8" SCHEDULE 40 PIPE	1	8" FLANGED TEE
4	8" FLANGED GATE VALVES	25	8" BASKETS
20	8"x8" 180° FLANGES	104	5/8"x5/8" BOLTS
6	8" 90° FLANGED ELBOWS	104	5/8" NUTS
TOOLS			
STANDARD CRAFT TOOLS			
2 - 18' STEP LADDERS			

STANDARD HOURS = 15.4  
ACTUAL HOURS =

Fig. 2.

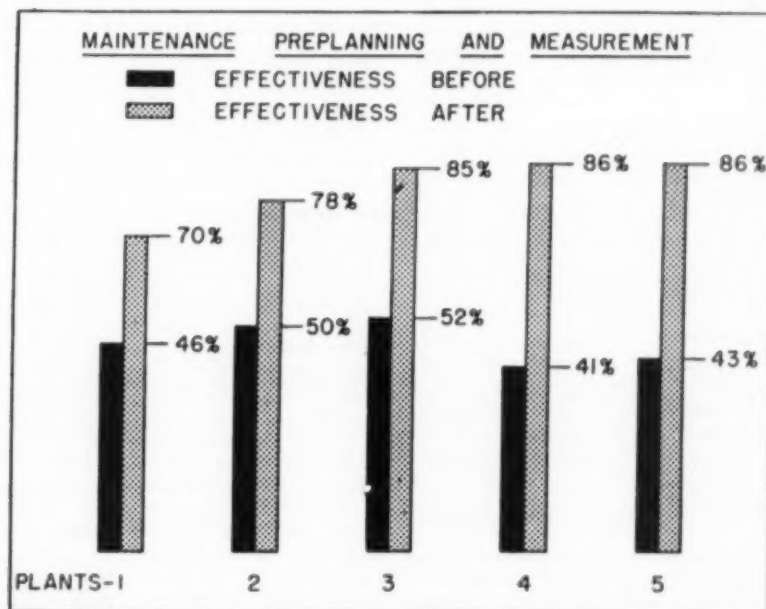


Fig. 3.



# ALUMINUM ALLOY REFERENCE SHEET

HARRY W. FRITTS — Aluminum Company of America, New Kensington, Pa.

## Wrought Alloys 525 and A545

### Commercial Products:

525—Sheet, plate, wire, rod, bar, tube.  
A545—Sheet, plate, wire, rod, bar.

**Applications and Remarks:** Because of better mechanical properties, alloy 525 is often used instead of 35, 45, or 50S in various applications. A545 is a relatively new commercial alloy. It is the highest strength commercially available nonheat-treatable aluminum alloy for sheet and plate. It appears to be ideally suited for pressure vessels, tank cars, tank trailers, and marine applications. Welding wire of A545 is being used successfully to join other aluminum alloys which heretofore could be welded only with aluminum-silicon wire (43S). Alloy 525 is included in section 8 of the 1952 A.S.M.E. Boiler and Pressure Vessel Code. Alloy A545 is approved for the fabrication of unfired pressure vessels under code case 1174.

**Composition:**  
525—2.5% Mg, 0.25% Cr, balance Al  
A545—3.5% Mg, 0.25% Cr, balance Al

## ALUMINUM ALLOY

### A.S.T.M. ALLOY DESIGNATIONS:

525 — GR20A  
A545 — GR40A

### A.S.T.M. SPECIFICATIONS:

B178, B209, B210, B211, B274  
B178, B273, B274

### MECHANICAL PROPERTIES:

	Temper Designations					
	—0	—H34	—H36	—0	—H34	—H36
Tensile strength, lb./sq.in.	27,000	37,000	41,000	35,000	42,000	48,000
Yield strength, lb./sq.in.	12,000	31,000	36,000	15,000	33,000	39,000
Elongation—% in 2 in.						
(1/16 in. sheet)	25	10	7	25	12	8
Shear strength, lb./sq.in.	18,000	21,000	24,000	22,000	25,000	28,000
Brinell hardness—500 kg. load, 10 mm. ball	45	67	75	57	78	87

### PHYSICAL PROPERTIES:

	525	A545
Modulus of elasticity, lb./sq.in.	10,100,000	10,100,000
Specific gravity	2.68	2.66
Weight—lb./cu.in.	0.097	0.096
Melting range, °F.	1100°-1200°	1094°-1193°
Thermal conductivity—B.t.u./hr. (sq.ft.) (°F./in.)	958 (—0)	840 (—0)
	958 (—H36)	840 (—H36)
Average coefficient of thermal expansion—in. °F. x 10 <sup>-6</sup>		
—76° — 4.68°	12.2	
68° — 212°	13.2	
68° — 392°	13.8	
68° — 572°	14.3	

Electrical conductivity—  
% of International Annealed Copper Standard

—35 (—0)	31 (—0)
—35 (—H36)	31 (—H36)

**Formability:** Both of these alloys have good formability. Relative to 35, they are somewhat harder to form. In machining, use high machine speeds and high rake angle. Cuttings will be stringy, however, chip breakers are more effective on these alloys, especially the harder tempers, than on the softer alloys.

**Heat Treatment:** Wrought alloys 525 and A545 are nonheat-treatable. Their strengths are considerably improved by cold working. The properties of the intermediate and hard tempers are stabilized by treatment at a slightly elevated temperature.

**Weldability:** These alloys can be welded by all the common methods but as with other aluminum alloys, inert gas shielded arc welding is preferred where flux removal is troublesome. They should be welded with A545 wire for best resistance to corrosion, strength, and elongation through the weld. These alloys are particularly suited for automatic welding by consumable electrode processes.

## CORROSION RESISTANCE

### Acids

Acetic, all concs., r.t.*	E
Acetic, other than glacial, boiling	P
Acetic glacial, boiling	E
Acetic anhydride, r.t.*	E
Acrylic, glacial, r.t.*	E
Benzoic, sat. soln, boiling	E
Boric, 7% soln., 180° F.	E
Butyric, all concs., r.t.*	E
Butyric anhydride, r.t.*	E
Carbolic (phenol), all concs., to 40° F.	E
Carbonic, all concs., r.t.*	E
Chromic, below 10%, r.t.	G
Cresylic (Cresol), r.t.	E
Fatty, up to boiling	E
Hydrochloric, all concs.	N
Hydrocyanic, all concs., r.t.*	E
Hydrofluoric, anhydrous, 200° F.	N
Hydrofluoric solutions	E
Lactic, anhydrous, r.t.*	E
Lactic, up to 10%, r.t.*	E
Maleic, 30%, r.t.	E
Maleic, anhydride, molten	E
Malic, to 50%, r.t.	E
Naphthenic, up to 180° F.	E
Nitric, above 82%, to 120° F.	E
Nitric, below 82%, r.t.	E
Nitric, red fuming, up to 120° F.	E
Oleic, up to boiling	E
Oxalic, all concs., r.t.*	G
Oxalic, all concs., elevated temperature	P
Phosphoric, all concs.	N
Phthalic, molten	E
Phthalic anhydride, molten	E
Propionic, all concs., r.t.*	E
Propionic anhydride, r.t.*	E
Stearic, up to boiling	E
Sulfuric, fuming	G
Sulfuric, other than fuming	N
Sulfurous, r.t.	E
Tannic, all concs., pure, r.t.	E
Tartaric, all concs., r.t.*	E

### Alkalies

Ammonium hydroxide, comm'l., r.t.*	E
Calcium hydroxide, all concs.	P
Potassium hydroxide, all concs.	N
Sodium hydroxide, all concs.	N

### Alkaline Salts

Potassium carbonate, all concs.	P
Sodium bicarbonate, r.t.*	E
Sodium carbonate, all concs.	P
Sodium sulfide	P

### Neutral Salts

Calcium chloride, all concs., to 200° F.	G
--	---

### RATINGS:

E—Excellent resistance. 0.001 max. in./year of penetration. Corrosion so slight as to be harmless.

G—Good resistance. 0.001-0.01 in./year of penetration. Satisfactory service expected; at most a slight etch.

F—Fair resistance. 0.01-0.1 in. of penetration/year. Satisfactory service under specific conditions. Light to moderate attack.

P—Poor resistance. 0.1-0.100 in. of penetration/year. Satisfactory for temporary service only.

N—Aluminum not recommended. Rate of attack high.

r.t.—Room temperature.

Glycerine, to boiling	E
Glycols, ethylene and propylene, r.t.*	E
Mercaptans, Amyl, r.t.*	E
Methyl Ethyl Ketone	E
Oils, crude, essential, refined, vegetable	E
Oils, sour crude (H.S.)	E
Trichloroethylene, dry, r.t.*	E

### Pickling Operations

Acetic Acid (Mag. Products)	E
Sulfuric plus dichromate	N
Sulfuric plus hydrochloric	N

### Food Industry

Brines, inhibited	E
Edible oils and fats	E
Fatty acids	E
Fruits and fruit juices	E
Vegetables	E
Milk products	E
Beer	E

### Paper Mill Applications

Kraft liquor	N
Black liquor	N
Green liquor	N
White liquor	F
Sulfite liquor	P
Chloride bleach solution	P
Chloride bleach vapors	G
Hydrogen peroxide (above 30%)	E
Paper makers alum	E
Humid and chemical atmospheres	E

### Photographic Industry

Humid atmospheres	E
Cellulose acetate	E
Acetic anhydride	E
Developers	E
Silver nitrate	P
Solutions containing SO <sub>2</sub>	P

### Fertilizer Industry

Ammonia, anhydrous	E
Ammoniated ammonium nitrate	E
Urea	E

\* Aluminum alloys used commercially.

\* Subject to pitting-type corrosion.

\* Must have trace of moisture present at boiling temperature.

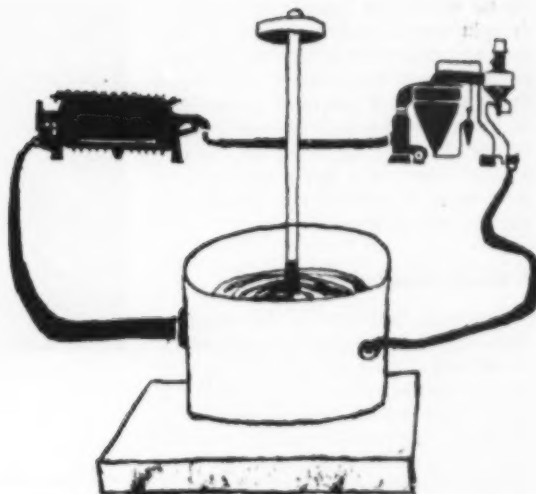
\* May be inhibited with sodium chromate.

No. 31



# A CHALLENGE TO ENGINEERS

George E. Holbrook



Slurry pressed, & dried —→

The major effort to cope with the growing complexity of science, business, and government has been ever-increasing specialization. This was impressively pointed out by Richard B. Morris, who recently compiled a list of 300 notable Americans from the *Encyclopedia of American History*. He said in part, "The list underscores the decline of versatility and the growing trend toward specialization. The bulk of those who made signal contributions to more than one field belonged to an era when it seemed feasible for a man to acquire an encyclopedic mastery of several disciplines. Today most of the intellectual disciplines are far more exacting and much more complex. With conspicuous exceptions, most of the notable Americans since 1850 have been specialists lacking that broad grasp of the humanities which characterized the great figures of our early history."

Looking forward, William H. Whyte, Jr., commented on what he calls "the new illiteracy,"

We hear much about the reawakening interest in the humanities, the new appreciation of the generalness in the liberal arts, the growing dissatisfaction with over-specialization. Maybe so. But these signs are minute, I suggest, to those coming from the other direction. I offer the proposition that the trends that have been working against the humanities are likely to increase, not decrease, in the decade ahead.

Further specialization, therefore, will result in even greater neglect of the humanities. It would be a sad outcome of the endeavor for scientific, industrial, and political efficiency to discover that we had become imaginatively sterile, narrow in vision, and uninspired intel-

Are we going in too much for specialization? Are we getting so involved in the labyrinthine ways of being educated that we are losing the true mean of a liberal education? Here, in the address of the 1953 winner of the Professional Progress Award in Chemical Engineering, George E. Holbrook, assistant director, development department, Du Pont Company, urges simplicity in the life of the chemical engineer himself and in his solutions of the problems confronting his day, whether he is engaged in research, production or sales.

Mr. Holbrook began his career with Du Pont as a research chemist in 1933 and has served in several capacities at the Jackson Laboratory, Chamber Works, and in Wilmington. For several months during 1952 he was on loan to the government, serving as director, chemical division, N.P.A. He has been active on A.I.Ch.E. committees including the Committee on Future of the Institute, and Constitution and By-Laws. He was a Director of the Institute (1950-1952).

He is the sixth recipient of the Professional Progress Award sponsored by the Celanese Corporation of America and administered by American Institute of Chemical Engineers.

lectually. It behooves us therefore to find some remedial measure that may be used as a supplement to specialization. A potent tool, possessing adequate merit in its own right, but untested as an accepted and universally applied mechanism, is *simplification*. This paper, accordingly, is particularly directed toward elucidating the value of simplicity and the specific challenge facing engineers in the struggle against complexity.

Just as early environment is responsible in the main for subsequent mature behavior, early and oft-repeated exposure to unwarranted complexity leads to complacent acceptance of its inevitability. It is important, therefore, that those concerned with education in the elementary and secondary schools reappraise teaching methods and subject matter in terms of simplified and realistic educational goals.

## Latin vs. Today's Needs

One wonders, for example, whether the student in today's circumstances can afford to study Latin as an indirect aid to English and the broader humanities,

or whether he might not better devote the equivalent time directly to subjects of recognized importance in their own right. The same question may be asked at the college level with respect to German and French. Some modern educators, however, have deplored the trend away from foreign languages. One of their reasons is that the philosophies developed in these foreign tongues are being ignored. It has been suggested, for example, that one might be well advised in view of international trends to study Chinese as a route to a better understanding of that philosophy. If for the purpose of discussion one accepts the value of Chinese philosophy, it seems justifiable to question the validity of the indirect approach which involves study of the Chinese language. Isn't the simple and most practical procedure the study of Chinese philosophy in translation? Other educators have deplored this foreign language fetish. Albert Edward Wiggam said, "The notion that culture results in some mysterious way from parsing Latin sentences or declining nouns, or digging for Greek roots is just as much a piece of magic as the

mystic words the South Sea Islanders thought they needed to make their boats float on water." It is time to stop juggling the pros and cons of this subject and holding final judgment in suspense. If all the evidence is not in, it never will be. Engineering educators can take a stand based on a desire and need for curriculum simplification to alleviate excessive specialization.

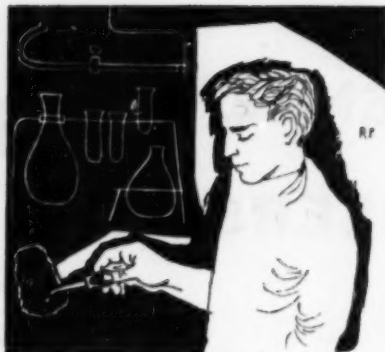
#### A Liberal Education Defined

It appears that the time has come for those engaged in teaching to review curricula and subject matter with simplification and directness specifically in mind. This is a challenge to the teachers of the engineering profession. Through their efforts even engineers may enjoy a truly "liberal education," which John Henry Cardinal Newman says, "teaches one to see things as they are, to go right to the point, to disentangle a skein of thought, to detect what is sophistical, and to discard what is irrelevant."

As the student engineer acquires interest in the literature of his field, it becomes abundantly clear to him that information is being added to our storehouse of knowledge at an ever-increasing rate. The effective application of this knowledge is a means for attaining further improvement in the standard of living and a fuller and more exalted life. Failure to reduce these increments of knowledge to their simplest form and to integrate them in proper perspective with previously developed information, results in confusion, dissipation of effort, and a slower rate of progress.

Many agree that the literature which is the permanent record of our scientific and technological information is replete with articles that either might better not have been published at all or else simplified and condensed to serve best the present and future needs. Nevertheless, there is as yet no united effort and no real community of interest and purpose to avoid this condition. Individuals occasionally endeavor to stem the tide, but early acceptance in life of the inevitability of complexity and the seemingly insatiable urge to publish inhibit a unified attack. Of considerable interest in this connection is a note in the September, 1953, issue of *Chemical Engineering Progress* by T. B. Drew, which reveals the urge to complicate. Referring to the naming of a new dimensionless group, he wrote, in part, as follows

My personal opinion is that there are now so many named dimensionless groups that one needs a card catalogue to keep run of them. The tendency . . . of some to present a paper in which the equations are made up almost exclusively of symbols such as  $N_{an}$ ,  $N_{pr}$ , and pure numbers seems



Analyzed ↓

to me to constitute a striving for elegance at the expense of clarity.

#### Need for Simplicity in Technical Literature

With respect to literature the problem is clear and certainly with respect to the permanent engineering literature the profession ought to face the issue squarely. Unless the policy of rigorously adhering to the principle of publishing new scientific truths in brief, simple, understandable terms is adopted, a morass of confusion, duplication, and mediocrity will result. The American Institute of Chemical Engineers has an opportunity to set this example. May it accept the challenge!

When the student engineer embarks upon an industrial career, he is further impressed with complexity as he is introduced to his new environment. In recognition of this situation orientation and training programs are provided to supply lubricants and sedatives for the transition. Undoubtedly many young

men wonder whether life has to be as complicated as it seems. However, in the rush to achieve rapid orientation, little time and few opportunities are available for such provocative questions. The urge is great to get the new employee into useful effort in the initial groove with the result that elucidation of broad simple principles is left to uninspired individual initiative. The attitude of accepting the inevitability of business complexity is thus unconsciously but solidly established. Isn't it probable that orientation can never be complete because it is in fact an endless effort to adjust to new vistas and ever-broadening horizons? A possible or at least partial solution to this problem would be the establishment of informal forums where questions might be raised and discussed. Such a procedure would provide fertile soil for the seeds of individual inquiry.

The young engineer next discovers that in research and development, in production and sales, it is frequently easier to reach a complicated solution than it is to attain a simple one. One wonders whether engineers are educated and disciplined adequately to see beyond the next experiment. By way of example, think back on the research experiences in the field of fractional distillation. From the early investigations of the perforated plate, research moved toward the exploration of towers packed with a wide variety of shapes and materials of construction. Then the bubble cap column caught the eye of research people and most of the conceivable types of caps and complicated designs were fully investigated. According to publications, current interest seems to be directed toward what can be viewed as a modification of the old perforated plate. Granting the criticism of hindsight, isn't it conceivable that had engineers struggled for *simplicity per se*, some thirty odd years might have been saved in arriving at these recently announced improvements?

Reviewing experiments encountered during the wartime conditions of the past ten years, one wonders why engineers cannot learn to enjoy some of the fruits of adversity instead of just suffering its rigors. Manifold are the examples of improved processes, substitution of alternate raw materials, use of less expensive materials of construction, and saving in manpower that really resulted from the simplification demanded by wartime conditions. Isn't it possible to attain and enjoy many of these benefits through the application of this concept? A book could be written on simplification resulting from the mere elimination of that which was *never* necessary or useful. The greater and more complex the initial blunder, the more illustrious the ultimate cure. One of the classics called

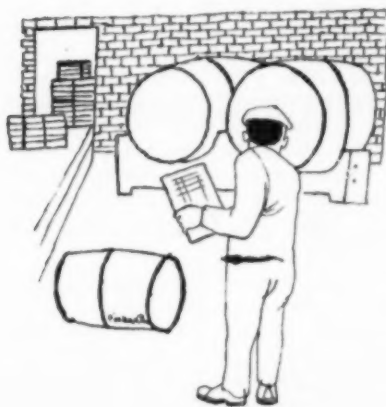




Stored ✓

to my attention was the case of a slurry, pumped to a press, the cake dried, analyzed, drummed, shipped to storage, requisitioned, returned to the same building, dumped into water, and reslurried for the next operation. Sounds incongruous, doesn't it? There *never* was any justification for the procedure. It just grew that way because no one with simplification in his soul saw the operation in its entirety.

Applications of the elaborate and dramatic in the fields of selling and advertising tend to foster analogous techniques in scientific areas. The urge, therefore, is frequently great to impress by overwhelming rather than to convince through the communication of simple facts and logic. Thus, in deviating from the simple and the direct, men tend to become slaves of techniques rather than masters of reason. Witness the current enthusiasm for "operations research," "servomechanisms," electronic "gadgets," and the "task-force" approach. They gained dramatic appeal as a result of applications during World War II.



Requisitioned →

Some, however, are old friends dressed up in new clothes. They have their place but only as means to justified ends. They are not ends in themselves. They should be used as any other tools whenever and wherever they provide the simple and effective route to the solution of a problem. After all, it is price and quality that determine acceptance in the market place, and techniques are no more identifiable in the final product than is calculus or geometry.

#### Timely Role of Chemical Engineer

Passing now from the narrower application of this principle in the field of technology to that possible in management, one sees an unusual opportunity for the enlightened chemical engineer. By academic training and industrial experience, the engineer should be in an ideal position to correlate and integrate for management in a simple, clear, and concise manner the complex technical and economic aspects of business problems. In this role the engineer possessed of objectivity and perspective can sweep aside confusing and frustrating side issues and comprehend problems in their naked simplicity. This is an essential step toward correct resolution and effective presentation to management. As an adviser to or participant in management, the engineer frequently has an opportunity to apply this viewpoint to matters of research, production, sales, organization, accounting, employee and public relations, corporate planning, and other facets of business. In these areas the tendency toward unnecessary complication is increased because here the philosophies and experiences of several professions frequently converge into a maelstrom of confusion that resolves itself into platitudes of compromise devoid of the advantages of any and endowed with the deficiencies of all.

Excessive and inappropriate use of

committees is another way to indulge in expensive business complexity. The committee is an excellent device in certain situations, but like strong medicine should be used, when diagnosis calls for it, sparingly and in the right places. As a court of review, a medium for final decision, or as a flywheel to balance the impetuous and the conservative, it may prove highly effective but as a substitute for an individual it is a poor device to get something done.

Management consultants are emphasizing the high cost of creating, handling, and filing office paper. Emmett J. Leahy, for example, has pointed out that clerical salaries now amount to one-ninth of the national income. Even in the chemical industry 16% of all employees handle paper rather than produce goods. The National Records Management Council estimates that reference is never made to 95% of all corporate paper work over a year old. Throwing it away, reducing extra copies, streamlining office procedures will all help, but the result will be far short of that possible if management does not see to it that simple things are kept simple. A management that condones complexity is just as delinquent as one that creates it. A disciplined engineer will find many challenging opportunities to aid management by not only cutting through red tape but finding ways to eliminate it and consistently refraining from creating it.

If at this time the reader is not enthusiastic about the value of simplicity and the challenging opportunities engineers have in making substantial contributions to science, mankind, and the future by practicing this principle, he may at least appreciate the brevity of these remarks. Simplification is attained not by wishing for it, not by talking about it, but, as in the case of safety, by practicing it.



& Reslurried.



## MEET THE NEW EDITOR

John B. Mellecker, Sr., widely known specialist on chemical engineering plant equipment and more recently known also for his studies of chemical engineers' information needs, joined *Chemical Engineering Progress* as associate editor on Feb. 15.

Since the end of the war, John had been Senior Technical Editor of *Chemical Engineering Catalog*. In this assignment he not only consulted with the manufacturers of about every type of equipment and materials used in process plants, but also became widely known among chemical engineers in industry as a source of engineering information.

He tells us that moving over to C.E.P.—particularly at the time when a program of changes has been authorized for the magazine—gives him just the increased radius of operation desired to expand his work on techniques of communication with chemical engineers.

John is, incidentally, a dogged funda-

mentalists—and asks the darndest questions: "Whom is this intended for?" "What are they expected to do with this information?" "Is this the simplest way of saying it?" . . . and so on.



J. B. Mellecker

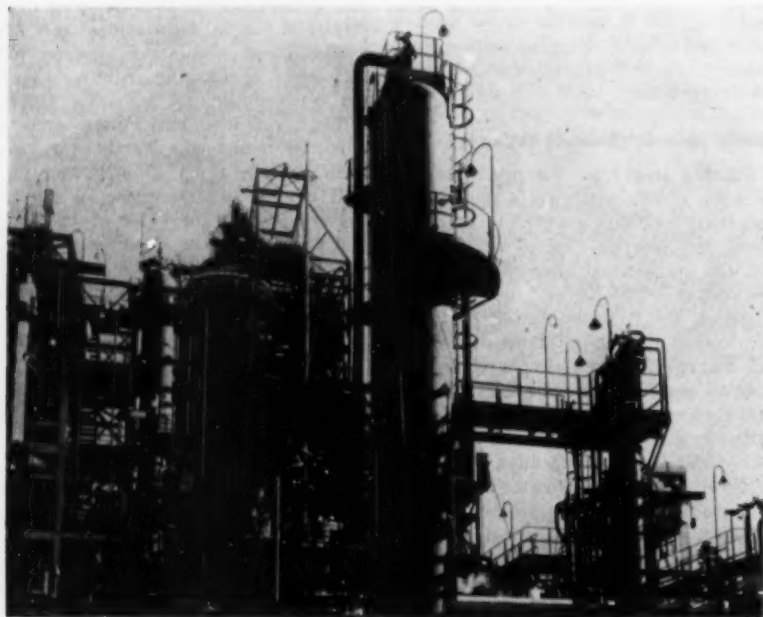
During the war he spent most of the time chasing around among thirteen firms engaged in the development of the light-weight body armor which proved

so effective in Korea. His job was "liaison," but stories still go around about the bullets that he fired into test specimens; the bullets are still lodged in the walls of Monsanto's research lab. in Springfield, Mass. Before this he was for a short period in chemicals manufacture, then became editor and market researcher for Reinhold Publishing; he edited a manual for operating and maintaining tanks sent overseas for the war, and was a wood preserver. The latter job arose from his work at Iowa State, where he received his Chemical Engineering degree. Until coming East in 1940, he developed Dowicide application processes for the protection of wood against fungus attack.

When we asked him about his hobbies, he replied, "For the foreseeable future there'll be time for only one, and that'll have to do with galley proofs." Ultimately, however, we expect him to settle back to sailing on Long Island Sound, water-color painting, and raising tropical fish and wire-haired terriers.

F.J.V.A.

### NEW CATFORMING UNIT FOR ATLANTIC REFINING



The first completed step in the \$50,000,000 modernization program of the Atlantic Refining Co. at Philadelphia is the Catforming unit, which will produce 500,000 gal. of higher-octane automotive gasoline daily. The new unit, opened recently, requires 40,000 lb. of Davison catalyst containing 2,680 oz. of platinum, valued at \$250,000. Other units, nearing completion, include a distillation unit with a running capacity of 50,000 bbl. of crude oil daily, a catalytic-cracking unit, and a 100-ton/day synthetic-ammonia plant, the first such plant in the Philadelphia area. The Catforming unit was built by Stone & Webster Engineering Corp.

### ALUMINA PRODUCTION INCREASES AT ALCOA

Expansion of facilities at the Mobile Alumina Works of Aluminum Co. of America to make the alumina plant the largest in the United States has been completed this month, according to a

company announcement. Alumina to make more than 100,000 tons of aluminum metal will be produced annually, requiring an additional seventy freight cars weekly to ship the increased output. Also an additional fifty ore ships annually will unload Caribbean bauxite.

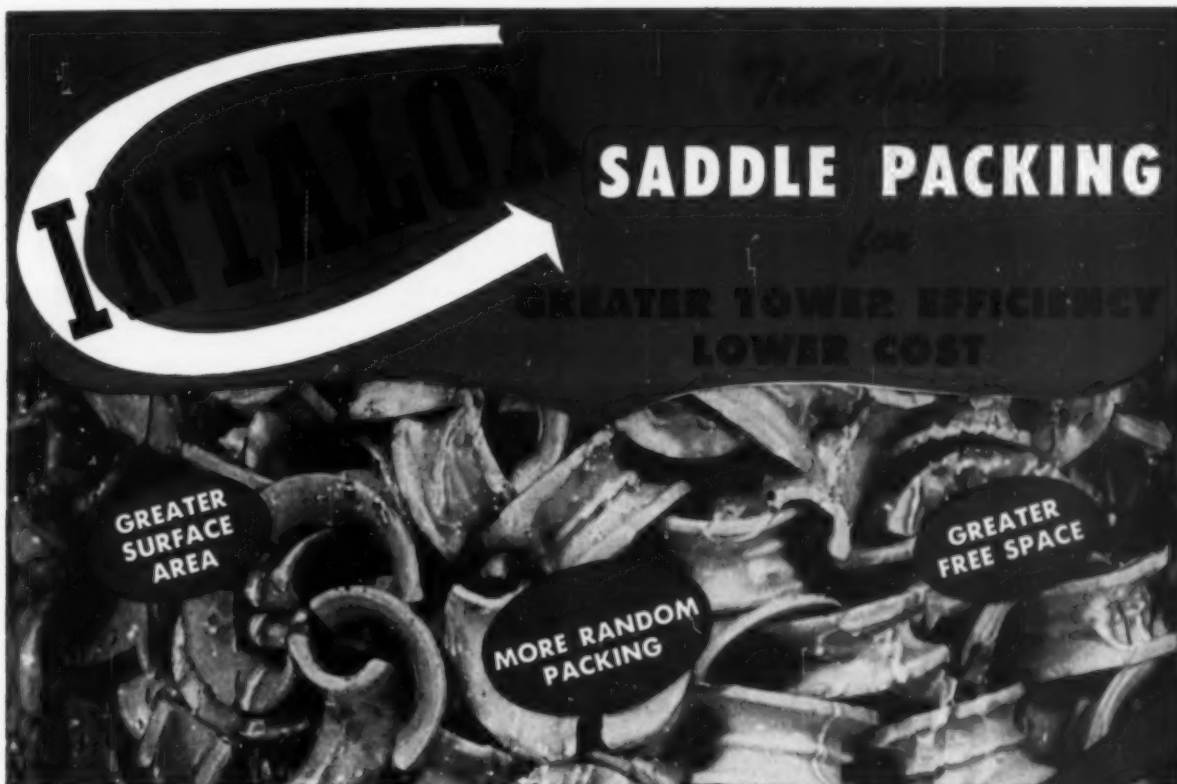
### USE FOR RADIOACTIVE WASTE AT ARGONNE LAB.

A new type of experimental radiation source that utilizes radioactive waste products has been developed at Argonne National Laboratory by the Chemical Engineering Division. To be used in food-sterilization studies, the source is a small hollow cylindrical block of concrete prepared by mixing cement and liquid radioactive fission products (the by-products created when neutrons bombard uranium 235 in a nuclear reactor). The mixture is surrounded on all sides, top, and bottom by several inches of ordinary concrete and a lead shield several inches thick, to protect experimenters from harmful radiation. Materials to be irradiated are lowered into the center of the source.



According to Stephen Lawroski, director of the division, the source is a significant forward step in the development of peacetime uses of atomic energy, as it possesses the following advantages: (1) the radioactivity used is obtained as a by-product and as such is inexpensive; (2) it provides an ideal method of disposing of the highly radioactive waste products; and (3) it provides for experimental use a radiation source of the type which will be used if large-scale food sterilization is feasible.

Bauxite may be handled both wet and dry in the new grinding facilities, which together with a digester unit, new filter presses and precipitators, and a new calcining kiln make up the bulk of the new installations for refining ore under the Bayer process.





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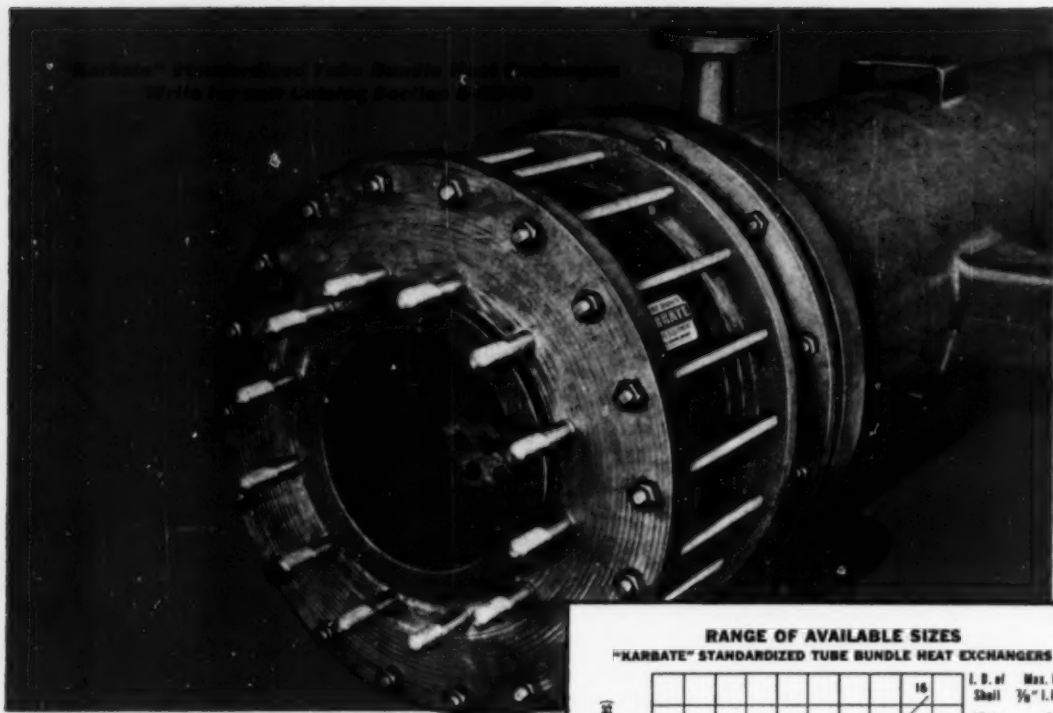
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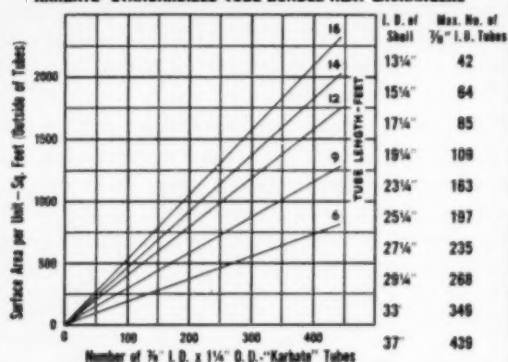
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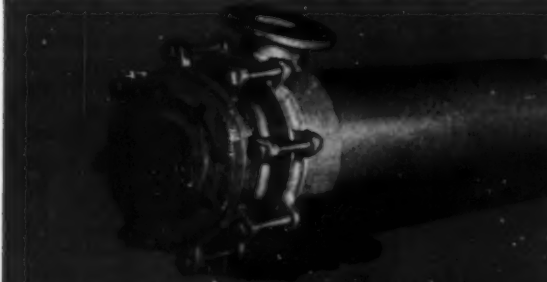
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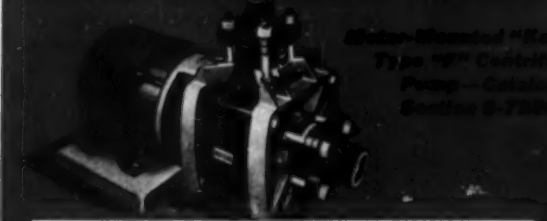
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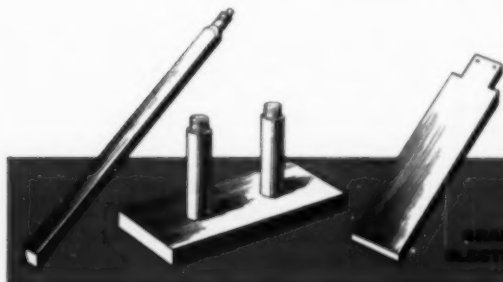
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## NEWS

(Continued from page 38)

### INDUSTRIAL WASTES MEETING IN APRIL

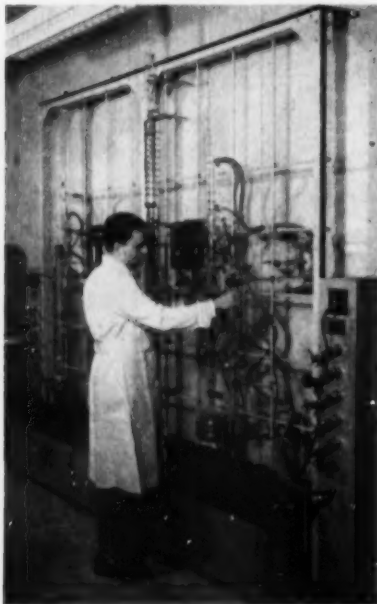
The 1954 Southern Industrial Wastes Conference, sponsored by the Manufacturing Chemists' Association, Inc., the Southern Association of Science and Industry, and the Texas Chemical Council, will be held at the Shamrock Hotel, Houston, Texas, from April 21 to 23.

Main topics of the meeting will be pollution problems in the industrial developing south, an air-pollution-control workshop, a water-pollution-control workshop, and pollution control in Texas. Papers will be presented by A. P. Black, president of the Southern Association of Science and Industry; C. K. Banks, vice-president, Metal and Thermit Corp.; William E. Rand, director of research, Stanford Research Institute; and others. W. I. Burt, vice-president, B. F. Goodrich Chemical Co., and former president, A.I.Ch.E., will preside over the air-pollution-control meeting.

At the conference banquet on April 22 the Southern Association of Science and Industry will present awards for distinguished service.

Further information and registration forms may be obtained from James D. Kittelton, Manufacturing Chemists' Association, Inc., 1625 Eye St., N. W., Washington 6, D. C.

### MALLINCKRODT OPENS FIRST UNIT OF NEW LABORATORY BUILDING



Distillation apparatus on one of the large racks that are a feature of each laboratory bay in the organic research laboratory, the first completed section of the new million-dollar laboratory building of Mallinckrodt Chemical Works, St. Louis, Mo.

## ONE-DAY MEETINGS OF LOCAL SECTIONS

### NEW JERSEY

Two simultaneous technical symposia "Solids Blending" and "New Techniques," followed by a luncheon, business meeting, and a nontechnical symposia on "Human Relations" will feature the all-day meeting of the New Jersey Section of A.I.Ch.E. to be held at the Essex House, Newark, N. J., on May 11.

William E. Catterall, Standard Oil Development, chairman of the symposium, has arranged for the presentation of three papers to be given on each of the aforementioned topics.

The program of papers is as follows:

#### Morning Session

##### SYMPOSIUM OF MIXING AND BLENDING

W. C. Sterb, Presiding

9:15—FUNDAMENTALS OF DRY MIXING AND BLENDING by Lincoln T. Work, consulting engineer, Slingmaster & Breyer, New York.

10:10—MIXING OF HIGH SOLID—LOW LIQUID MASSES

11:05—FLUID DISPERSION SYSTEMS by L. H. Reef, Manton-Gaulin Mfg. Co., Everett, Mass.

##### SYMPOSIUM ON NEW TECHNIQUES IN CHEMICAL ENGINEERING

A. B. Welty, Jr., Presiding

9:15—USE OF FREQUENCY RESPONSE IN ANALYSIS OF CHEMICAL ENGINEERING PROCESSES by Ernest F. Johnson, assistant professor of chemical engineering, Princeton University.

10:10—RECENT SOLUTIONS TO PUMPING PROBLEMS by C. B. Mitchell, Engineering Services Division, Du Pont Co., Newark, Del.

11:05—THE APPLICATION OF STRAIN GAUGE DEVICES TO PROCESS INDUSTRIES by Edgar J. Jones, Ruge-deForest, Cambridge, Mass.

#### Afternoon Session

##### HUMAN RELATIONS

C. E. Strong, Presiding

FROM THE STARS IN THE SKY TO THE STARS IN THE SKYSCRAPER, OR THE SCIENCE OF BEING SCIENTIFIC by F. F. Bradshaw, Richardson, Bellows, Henry and Co., New York.

3:00—THE HUMAN SIDE OF LIVING by Kenneth Connell, director, Dale Carnegie courses in New Jersey from New York.

3:30—JOHNSON & JOHNSON EXPERIENCE IN HUMAN RELATIONS by a representative of the Johnson & Johnson Co., New Brunswick, N. J.

### BOSTON

The Fourth Annual Symposium of the Ichthyologists (Boston Section, A.I.Ch.E.) will be held April 14, 1954, at John Hancock Hall, Boston.

The program will consider nuclear energy as a new source for industrial power in New England. Enterprise Unlimited, complete with Board of Directors and Research Staff, will consider whether it should now invest its own capital in the use of nuclear energy for a central power station. Last year Enterprise Unlimited considered the location of an ammonia plant in New England at the third annual symposium. There was considerable interest on the part of potential ammonia producers and since that time one firm has been granted a Certificate of Necessity for construction of an ammonia plant in New England.

Manson Benedict, as director of research, will receive reports from his staff and will make recommendations to the board of directors. Three papers will be presented this year: "Future Power Requirements in New England," "Engineering of Nuclear Power Systems," and "Nuclear Power Economics."

### PHILADELPHIA- WILMINGTON

The second annual one-day meeting sponsored jointly by the Philadelphia-Wilmington Section of A.I.Ch.E. and the University of Pennsylvania will be held on April 27, 1954, at the University Museum, on the Penn campus in Philadelphia. J. I. Harper, Sun Oil Co., is general chairman. The meeting will be the second of an "Experience in Industry" series. The broad topic this year will be "Distillation in Practice."

A welcoming address will be delivered by M. C. Molstad, University of Pennsylvania, and introductory remarks made by J. I. Harper, the chairman. Before luncheon to be held in Houston Hall, University of Pennsylvania, a general discussion is scheduled, and following the afternoon program and before dinner, another general discussion is on the agenda. Dinner will be served at the Penn-Sherwood Hotel. Charles C. Chambers, vice-president in charge of engineering affairs, University of Pennsylvania, will speak.

The Zeisberg Memorial Awards will be made at this time.

The technical program for the session is as follows:

#### Morning Session

9:30—THE EVALUATION OF DISTILLING TECHNIQUES by Allan P. Colburn, provost, University of Delaware.



**9:30—OVER-ALL COLUMN DESIGN FROM A PROCESS VIEWPOINT** by Cyrus Pyle, research manager, Engineering Research Laboratory, Du Pont Co., Wilmington, Del.

**10:35—PHYSICAL DESIGN FEATURES OF PLATE COLUMNS** by Ray L. Geddes, consultant, Badger Division, Stone & Webster Engineering Corp., Boston, Mass.

**11:05—TECHNIQUES IN PETROLEUM FRACTIONATION** by Charles H. Brooks, process engineer, Sun Oil Co., Philadelphia.

#### Afternoon Session

**2:30—INSTRUMENTATION AND CONTROL OF DISTILLATION EQUIPMENT** by Ward O'Connor, manager, Mechanical Engineering, The Lummus Co., New York.

**3:00—OPERATION OF DISTILLATION EQUIPMENT** by Charles E. Strong, acetic acid operating supervisor, Hercules Powder Co., Parlin, N. J.

**3:45—SOME COMMERCIAL ASPECTS OF VACUUM DISTILLATION** by William A. Hall, director, Engineering Division, Research and Development Department, Atlantic Refining Co., Philadelphia.

#### E. J. C. ANNOUNCES 1954 OFFICERS

The new slate of officers for 1954 of the Engineers Joint Council includes Thorndike Saville, dean of the college of engineering at New York University, as president; Carlton S. Proctor, president of Moran, Proctor, Mueser, and Rutledge, as vice-president; and the following members of the executive committee: W. M. Peirce, representing A.I.M.E.; F. S. Blackall, Jr., A.S.M.E.; C. H. Capen, American Water Works Association; W. J. Barrett, A.I.E.E.; L. R. Sanford, The Society of Naval Architects and Marine Engineers; and C. G. Kirkbride, A.I.Ch.E.

#### SCIENCE TEACHERS AS SUMMER EMPLOYEES

Industry and education both will benefit from summer employment of high school science teachers in plants and laboratories affiliated with their fields, according to the Future Scientists of America Foundation, an activity of the National Science Teachers Association. In a pamphlet obtainable from its office at 1201 16th St., N.W., Washington 6, D. C., the foundation explains that the present manpower shortage in engineering and other scientific fields is in part traceable to lack of high-school preparation of able students. By offering summer employment to teachers, the foundation stresses, industry can improve their practical knowledge, encourage them to remain in the teaching field, and avail itself of a source of trained temporary personnel during vacation periods. Suggestions for reaching the teachers are contained in the booklet.



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1429 SOUTH EASTERN AVENUE • LOS ANGELES 22, CALIFORNIA

## From one source . . . any instrumentation you need

When it comes to measurement and control, every industrial process is different. Each demands its own combination of accuracy, economy, instrument ranges, and all the numerous other characteristics that are peculiar to the individual application.

No single instrument and its accessories could possibly fit every process. So Honeywell makes a broad variety of measuring and controlling equipment that spreads across a tremendous range of applications.

The advantages are two-fold. First, you can get all the instrumentation your process requires from a single source, so there is undivided responsibility for the complete installation. And second, you are assured that the equipment selected for your process is recommended without bias . . . neither over-sells nor under-equip . . . needs no stretching, squeezing or compromising to fit it to its assignment.

This versatile family includes *ElectroniK* indicators, recorders and controllers in circular and strip chart models, applicable to temperature, pressure, pH, power and dozens of other variables; square root flow meters for control applications; evenly graduated flow meters for cost accounting; thermometers, pressure gauges and liquid level meters; *Pyr-O-Vane* millivoltmeter controllers. Especially useful for graphic panels are the *Tel-O-Set* miniature indicators, recorders and controllers. Electric and pneumatic control systems range from the simplest to the most complex, including automatic program controls and complete systems developed for particular processes.

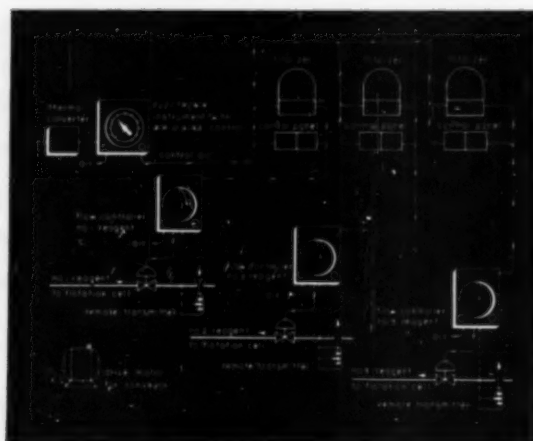
Working with these instruments is a full choice of primary elements . . . thermocouples, *Radiamatic* radiation elements, pressure-type and electrical resistance thermal systems, flow meter bodies, pH cells and many others. For final control elements, you can choose from a wide range of electric motorized and diaphragm operated valves. To complete the picture, there are more than 7000 non-indicating devices for controlling temperature, pressure, vacuum, liquid level and humidity . . . an unmatched variety of instrumentation made by the world's largest manufacturer of control equipment.

# *ElectroniK*

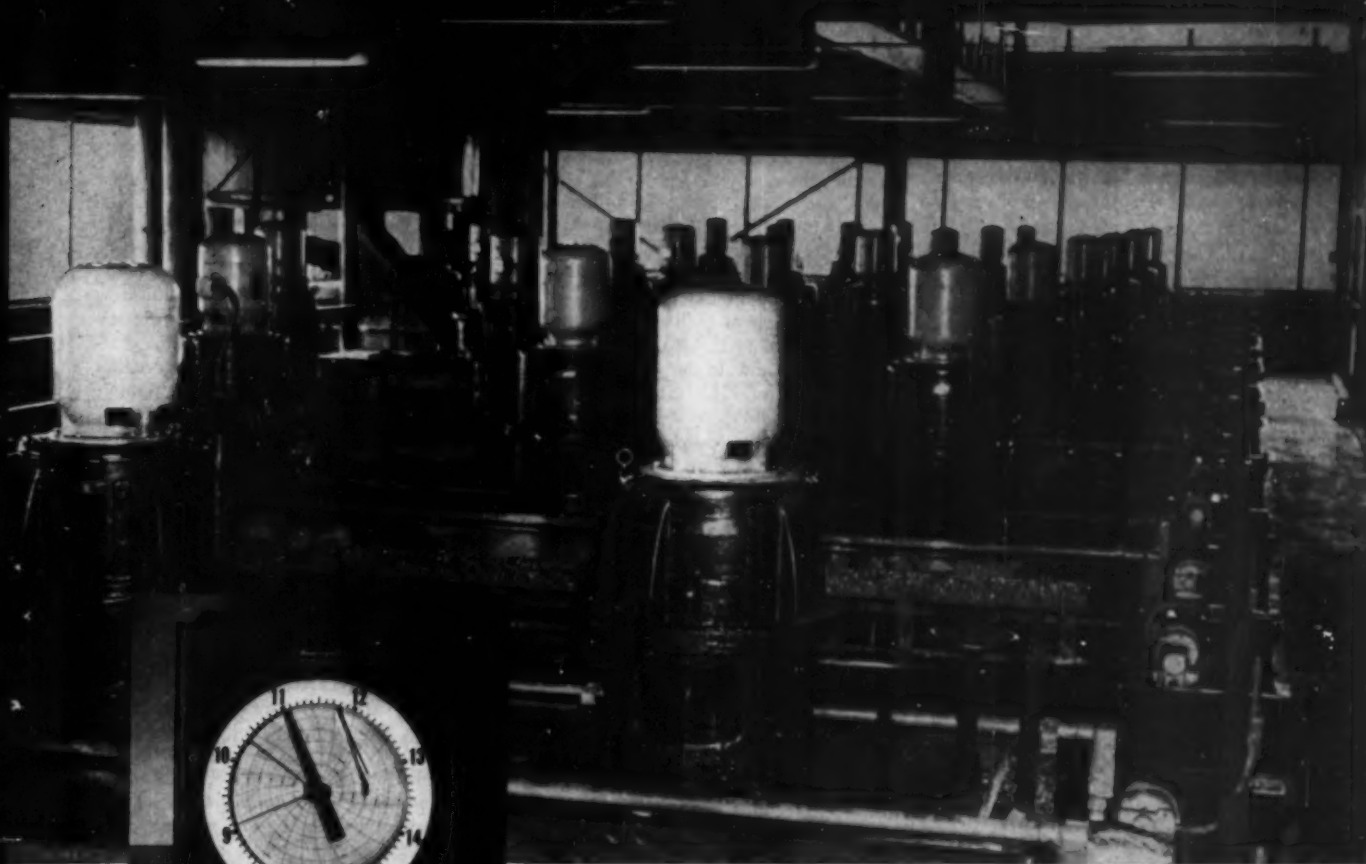
## pH control

## helps increase

## the yield from



Schematic diagram of pH control system for addition of caustic to phosphate flotation process.



*Addition of caustic to these flotation cells is automatically regulated by ElectroniK pH Controllers, at the Noralyn plant of International Minerals and Chemical Corporation, of Bartow, Florida.*

## phosphate ore beneficiation

**T**HE APPLICATIONS of *ElectroniK* instrumentation to the beneficiation of phosphate ore, at International Minerals and Chemical Corporation, demonstrate how modern control techniques help make heavy chemical processing more automatic . . . more efficient.

The flotation process, where silica sand is removed from the phosphate slurry, operates best within close pH limits. Through the use of an *ElectroniK* pH Controller, caustic is automatically added at the proper rate to maintain the desired alkalinity. A sample of slurry is continuously withdrawn from one of the flotation cells, and the liquid is passed through a pH electrode assembly. Connected to this detecting element through an amplifier is an *ElectroniK* instrument, which records the pH value and, through its *Air-O-Line* control, resets a caustic flow controller.

The complete system provides sensitive, accurate adjustment of caustic flow . . . holds pH well within the desired tolerances for peak production.

Instrumentation by Honeywell puts top performance into today's process control systems. Through years of experience in chemical processing problems, Honeywell specialists are qualified to engineer the kind of control your process needs, by utilizing the uniquely wide variety of recording and controlling instruments which Honeywell has developed for this field.

Your nearby Honeywell sales engineer will welcome the opportunity to discuss your specific application . . . and he's as near as your phone.

MINNEAPOLIS-HONEYWELL REGULATOR Co., Industrial Division, Wayne and Windrim Avenues, Philadelphia 44, Pa.

● REFERENCE DATA: Write for Catalog 1550, "pH and Conductivity Recorders and Controllers," and for Catalog 1531, "ElectroniK Controllers."



MINNEAPOLIS  
**Honeywell**  
BROWN INSTRUMENTS

*First in Controls*



## GULF UPS ETHYLENE OUTPUT FOR 1955

A 10% increase in the nation's ethylene production is forecast by Gulf Oil Corp. as a result of the new ethylene plant that it plans to erect, together with a new platforming unit, at its Port Arthur, Texas, refinery.

The ethylene unit, which is expected to have a capacity of 3,000,000,000 cu. ft. of ethylene gas a year, will use as its charge stock propane and other gases produced in refining. The main plant will comprise a series of fractionating towers for separating ethylene, ethane, and other hydrocarbons and a series of cracking furnaces for converting the propane and ethane to ethylene, which will be distributed direct to consumers through company pipelines.

Capacity of the platforming unit is announced as 29,000 bbl. a stream day of high-octane motor gasoline, produced by the platinum catalyst method developed by the Universal Oil Products Co.

Although not related functionally, the two units have in common the fact that neither will require an increase in the crude charged to the refinery.

Construction of both units, at an undisclosed cost, is scheduled to begin this spring and to be finished in the first quarter of 1955. Stone & Webster Engineering Corp. will handle the construction of the ethylene unit, which includes a power plant. Fluor Corp. will erect the platforming unit.

## DORR DESIGNS FOREIGN FERTILIZER PLANTS

Two chemical fertilizer plants utilizing a process that requires no evapora-

tion of phosphoric acid are being designed by The Dorr Co., Stamford, Conn., for a firm at Minimata, Japan, and one at Odda, Norway, the company recently announced.

The Japanese plant, constructed by Shin Nippon Chisso Hiryo K.K., will produce granular ammonium phosphate. Intermediate phosphoric acid containing 28%  $P_2O_5$  will be made from low-grade 70%  $H_2SO_4$  as a starting material.

The Det Norske Zinkkompani A/S plant will produce concentrated phosphoric acid for the manufacture of triple superphosphate. Sulfur dioxide from zinc roasters will be the starting material for the production of  $H_2SO_4$  used in the process.

## FRANCE GETS FIRST STYRENE MONOMER PLANT

The first styrene monomer plant in France will be constructed and operated under the direction of Koppers Co., Inc., it was recently announced by B. J. C. van der Hoeven, vice-president and assistant general manager of Koppers chemical division. The plant will be erected for the Société Houillères-Pechiney-Progil at Mazingarbe. Two Koppers divisions, the engineering and construction and the chemical, will participate in the contract. Actual building is expected to take at least two years. The plant will have a rated capacity of from 10,000 to 14,000 metric tons annually.

## BREA CHEMICALS ADDS TO CALIFORNIA PLANT

Brea Chemicals, Inc., a subsidiary of Union Oil Co. of California, is planning a \$2,500,000 nitric acid and ammonium nitrate plant at Brea, Calif., adjacent to the Amniaco Corp. ammonia plant, which will also be operated by Brea Chemicals.

## PARIS WILL HOLD ALUMINUM CONGRESS

A scientific congress and exhibition will be held in Paris from June 14 to 19 by La Société Chimique de France and L'Aluminium Français to celebrate the centenary of the first production of industrial aluminum in France by Henry Sainte-Claire Deville.

The congress will include discussion of papers dealing with aluminum metallurgy, chemistry and physicochemistry of aluminum compounds, and technology and uses of aluminum and aluminum alloys, and visits to plants and laboratories in Paris and other parts of France. Further information may be obtained from R. Gadeau, Secretary, L'Aluminium Français, 23 Rue Balzac, Paris 8, France.

(More News on page 48)

## NEW OXIDATION PROCESS USED AT SPENCER CHEMICALS



The new anhydrous ammonia plant of Spencer Chemical Co. now on stream at Vicksburg, Miss., is announced by the company to be the first commercial operation of the Texaco partial oxidation process for the production of commercially pure hydrogen for subsequent purification and synthesis to ammonia.

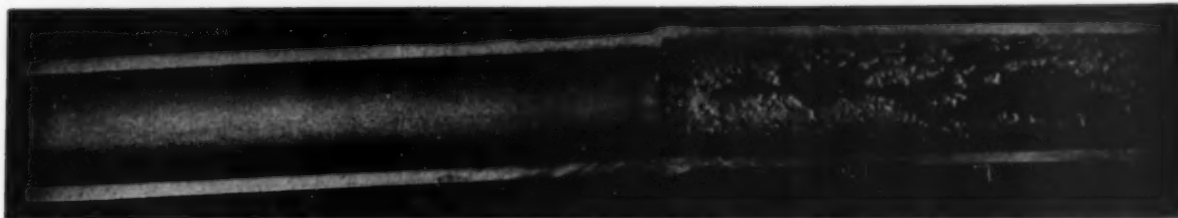
Completion of its anhydrous ammonia plant at Vicksburg, Miss., was recently announced by Spencer Chemical Co. The first to use the Texaco partial oxidation process (direct thermal reforming) for the production of commercially pure hydrogen, the new synthesis gas plant was designed and constructed by Foster Wheeler Corp.

In this partial oxidation process commercially pure oxygen and natural gas are brought together under pressure (without catalyst) in a converter of simple design. The product of this conversion, essentially hydrogen and carbon monoxide, passes to a shift converter, where in the presence of a catalyst and water the carbon monoxide is

converted to carbon dioxide, and additional hydrogen is produced from the dissociation of the water during the shift reaction. The raw synthesis gas is then purified for removal of carbon dioxide and finally passes through a liquid nitrogen wash from which hydrogen of 99+-% purity is mixed with commercially pure nitrogen for subsequent ammonia synthesis. The ammonia-synthesis plant was designed and constructed by Spencer.

The commercially pure oxygen is obtained from an air-separation unit that liquefies 1,000 tons of air a day and fractionally separates it into commercially pure nitrogen and oxygen. The unit was designed by Air Products, Inc.





Comparison of resistance to corrosion. This photograph of tubing subjected to corrosion by gas condensate in the petroleum industry shows (left) condition of internally nickel plated section after 18 months' service, and (right) bare steel tubing in service for 12 months. (Photographs courtesy of Bart Manufacturing Co., Bellville, N. J.)

Now you can specify . . .

## Seamless Steel Pipe with Integral Lining of Pure Nickel

A pore-free, adherent, nickel coating can be made an integral part of steel pipe and fittings by new techniques and plating equipment.

Standard thicknesses of pure nickel deposited on the inside surfaces range from .007" to .015". Heavier deposits are laid where required.

Applications of nickel-lined pipe are increasing in fields such as the following:

### ORGANIC CHEMICALS

Phenol, glycerine, alcohol, formaldehyde and chlorinated organics, as well as many other liquids and gases can be handled by nickel-lined pipe at low rates of corrosion.

### CAUSTIC SODA

For concentrations up to 73%, caustic producers and users, alike, find nickel-lined pipe particularly satisfactory for controlling corrosion as well as product purity. Furthermore, the newly produced nickel-lined fittings allow wide choice of welded fittings.

### PULP AND PAPER

Nickel-coated steel pipe combines the corrosion-resistance of nickel with the structural strength of seamless piping to provide a superior means of handling hot caustic liquors, green or black. It is not, however, recommended for use where a high free chlorine content exists in the aqueous media, nor to handle sulfurous acid.

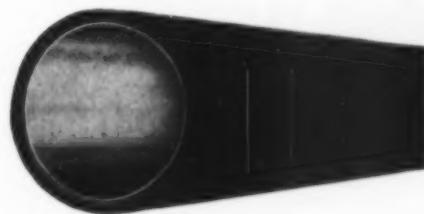
### NATURAL GAS PRODUCTION

Nickel-lined pipe answers the sour and sweet distillate corrosion problem by providing control for prolonged periods under severe condensate conditions. Advent of sealing type joints for nickel-lined tubing helps solve the old problem of plating API threaded joints.

### WATER SYSTEMS

Where water requirements call for high purity, deionizing processes may be used. Nickel-lined pipe proves ideal for handling such deionized waters. It also controls chloride corrosion from brackish water such as that used in Gulf Coast areas as a coolant.

Whatever your industry...when you have a metal problem, send us details for our suggestions.



The unbroken interior surface of nickel-lined pipe attests to success of new plating techniques and newly developed equipment. This is a solution to many corrosion and contamination problems.



**THE INTERNATIONAL NICKEL COMPANY, INC.** 67 WALL STREET  
NEW YORK 5, N. Y.

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**VACUUM PUMP  
 MAINTENANCE  
 COSTS and BETTER  
 VACUUM...**

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**HILCO OIL RECLAIMER**

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**Oil  
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A simple, economical and efficient method of restoring contaminated lubricating and sealing oil to the full value of **NEW OIL**. The HILCO will produce and maintain oil free of solids, gums, water and gases in a continuous, all-electric, automatic operation.

Be **SURE** of clean oil in your  
**HIGH VACUUM PUMPS**

**HILCO**  
**OIL RECLAIMER  
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**IN CANADA — UPTON-BRADEEN-JAMES, Ltd.**

**890 Bay St., Toronto, 3464 Park Ave., Montreal**

## DIATOMITE QUARRIED BY NEW METHOD

Acquisition of the right to quarry a 165-acre diatomite deposit near Waltheria, Calif., has been announced by the Great Lakes Carbon Corp. The Waltheria plant of its Dicalite Division will process the ore, which will be obtained through a new type of operation, the trenching method, or borrow-pit system, of ore extraction.

By this method the deposit, which consists of a top layer of overburden and alternate layers of diatomite and overburden, will be worked by trenching the earth, extracting the ore, and refilling the trench behind the operation, all without dust, noise, or disfiguring apparatus to disturb the essentially residential area.

Great Lakes Carbon gained control of the land on which the deposit is situated in December, 1953, and engaged a planning group to devise a master plan that preserves the natural beauty of the area while providing for both the quarry operation and a residential section containing over 10,000 homesites.

## NEW RESISTANT HOSE AND PIPE

New pipe and hose made of a Teflon compound have been announced by Resistoflex Corp., Belleville, N. J. Good chemical inertness (except in the presence of molten alkali metals and chlorine trifluoride at high temperatures, utilization in a wide temperature range ( $-100^{\circ}$  to  $500^{\circ}$  F.), high dielectric qualities, and low coefficient of friction are the properties claimed for the material, called Fluoroflex-T. The hose is completely flexible and is available in sizes of  $\frac{1}{4}$  to 1 in. The pipe, which is made of the Teflon compound laminated with glass fabric, is available in diameters from 1 to 4 in. and can be cut and fitted on the job.

## BONILLA ADVISES CUBAN RESEARCH INSTITUTE

An industrial research institute with Charles F. Bonilla, professor of chemical engineering at Columbia University, New York, as adviser has recently been established at the University of Villanueva, Cuba. The initial program, working with a grant of \$100,000, will concentrate on the sugar industry, according to Dr. Bonilla.

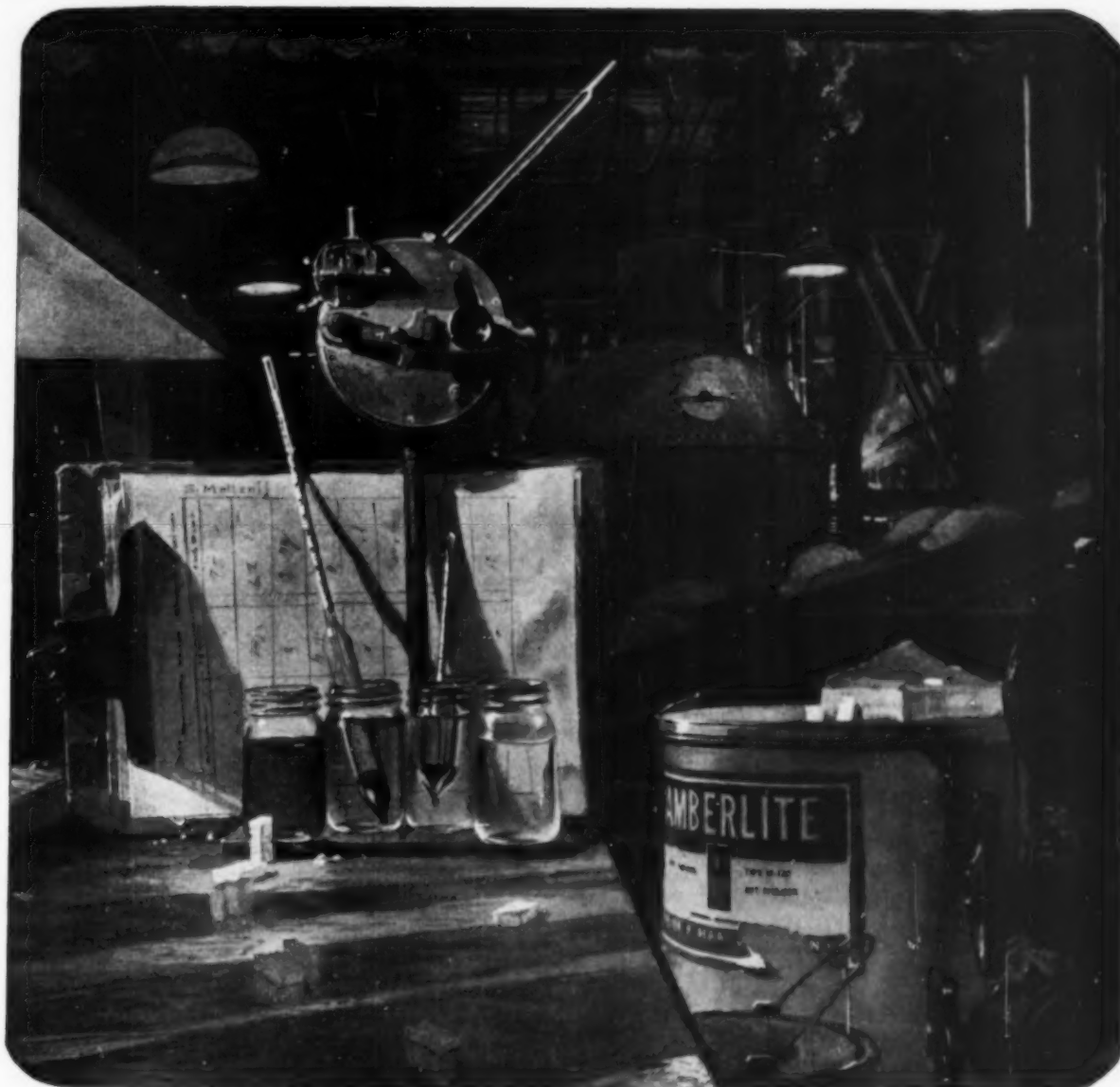
Also at the university a chemical engineering building is being completed at a cost of \$600,000 for construction and equipment. The chemical engineering curriculum extends for five years and was organized in 1951.

## A.E.C. AWARDS NEW CONTRACTS

The award of forty-two unclassified physical research contracts with universities, private research institutions, and industrial laboratories was recently announced by the U. S. Atomic Energy Commission. The contracts, generally for a term of 1 year, were let as part of the A.E.C.'s continuing policy of utilizing private research laboratories in conducting research related to atomic energy. Research costs are borne by the institutions, which contribute the funds and services they normally devote to work in the field, and by the Commission, which provides additional funds for equipment and salaries of research associates and assistants. Among the contracts are "Isotopic Exchange Reactions," \$14,410 at the University of California; "Nuclear Chemistry Research," \$42,552 at the Carnegie Institute of Technology; "Nuclear Chemistry Research," \$141,700, at Massachusetts Institute of Technology; "Polarographic Behavior of Organic Compounds," \$12,400 at University of Michigan; "Low-Temperature Chemical Thermodynamics," \$8,316 at University of Michigan.

Other contracts are "Mechanism of Substitution Reactions of Inorganic Complexes," \$6,696 at Northwestern University; "Study of Gaseous Chemical Reaction Kinetics, Using a Mass Spectrometer," \$9,000 at University of Oregon; "Application of Chemical Thermodynamics to the Study of Metallic Alloy Formation," \$13,702 at University of Pittsburgh; "Research in Nuclear Reactions with Fast Alpha Particles, Neutrons, and Deuterons and a Study of Nuclear Structure," \$50,000 at Purdue Research Foundation; "Self-Diffusion and High-Temperature Phenomena," \$40,000 at Sylvania Electric Products, Inc.; "Cociprecipitation Studies," \$12,500 at Syracuse University; "Studies on the Direct Measurement of the Energy Changes Resulting from Plastic Deformation and Phase Transformations," \$8,300 at University of Tennessee; "Rates of Catalytic Reactions Involving Deuterium and Relative Vapor Pressures of Water and Deuterium Oxide in the Presence of Certain Salts," \$6,402 at University of Tennessee; "Mass-Transfer Studies in Liquid-Liquid Extraction," \$2,673 at Virginia Engineering Experiment Station; "Permeability Method of Determining Surface Areas of Finely Divided Materials," \$15,300 at University of Wichita Foundation for Industrial Research; "Low-Temperature Research," \$8,095 at University of Wisconsin.

(More News on page 50)



## Sugar by the ton: 99.99% pure

There aren't many chemicals—let alone foodstuffs—as chemically pure as sugar prepared from sirups treated with Amberlite® ion exchange resins. These resins remove ash from cane sirup solutions, cut down sugar loss in molasses, yield sugar of the highest quality.

Other products, too, benefit from proper treatment with the Amberlite ion exchangers. Soft curd milk for infants may be produced from cow's milk, for example. Stabilized cream and condensed milk, readily soluble in hot drinks, may be prepared. Crude glycerin can be converted to C.P. grade by an ion exchange process.

The list is long. Gelatin, amino acids, fruit drinks, bland sirups from fruit wastes, vitamins, dextrose sirups, and others may be purified at low cost by means of Amberlite ion exchange.

Why not write us about your problem . . . ask us about Amberlite ion exchange resins? Take this opportunity to find out why, in ion exchange, the right way is the Amberlite way.

Ask for "Amberlite Ion Exchange," 16 pages of technical information on the applications for ion exchange in industry.

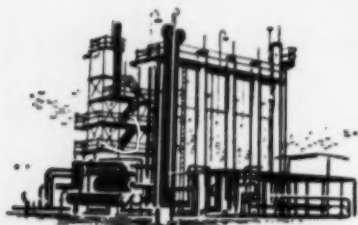


# ROHM & HAAS COMPANY

THE RESINOUS PRODUCTS DIVISION, PHILADELPHIA 5, PENNSYLVANIA

## PROBLEM

To produce hydrogen essentially free of carbon monoxide which has a deleterious effect on product quality and plant capacity for edible oil producers.



## SOLUTION

GIRDLER developed a highly active durable catalyst, G-12, for removal of carbon monoxide from the hydrogen. Cost of hydrogen production was reduced and carbon monoxide content was cut 95% resulting in:

**Hydrogen with  
less than 5ppm of  
carbon monoxide**



Take advantage of the experience of Girdler in solving *your* catalyst problems!

FOR

*Catalysts*

WRITE...



The  
**GIRDLER**  
Company

A DIVISION OF  
NATIONAL CYLINDER GAS COMPANY  
Gas Processors Division  
LOUISVILLE 1, KENTUCKY  
NEW YORK • TULSA • SAN FRANCISCO

## CLAY IS SUBJECT OF PACIFIC CONFERENCE

The clay-water system will be the subject of the 1954 Pacific Coast Regional Conference on Clays and Clay Technology to be held at the University of California, Berkeley, on June 25 and 26. Papers related to permeability of liquids through formations, swelling of clays, viscosity, and plasticity will be presented from the fields of petroleum, soil science, soil mechanics, geophysics, and ceramics. Details of the conference may be secured from George L. Gates, Bureau of Mines, 630 Sansome St., San Francisco 11, Calif.

## A. S. A. STANDARDS ANNOUNCED FOR 1954

Among the 266 standards coordinated and approved by the American Standards Association in 1953, several are of interest to chemical engineers and chemists: the test for foaming characteristics of crankcase oils, for butadiene dimer in polymerization-grade butadiene, for boiling-point range of polymerization-grade butadiene, for carbonyl content of butadiene, and for water tolerance of aircraft fuels, and the A.S.T.M.-I.P. petroleum measurement tables.

Of the 266, there were 81 new standards; the rest were revised. The greatest number of new standards were in civil engineering and construction.

## MICHIGAN OFFERS SHORT COURSE IN AUTOMATION

Two intensive courses in automatic control will be offered at the College of Engineering, University of Michigan, in June. The first, which covers the fundamental principles and applications of measurement, communication, and control, will extend from June 14 to 19. Applications of the fundamentals to more advanced problems will comprise the second course, from June 21 to 23. Use will be made in both courses of computing, instrumentation, and servo laboratories on the campus. Closing date for registration is April 15. Further information may be obtained from Professor M. H. Nichols, room 1523, East Engineering Building, University of Michigan, Ann Arbor, Mich.

## NATIONAL SCIENCE FOUNDATION GRANTS

Among the one hundred grants recently made by the National Science Foundation in support of the biological and physical sciences, four went toward research in engineering sciences. Of

these, two were in chemical engineering, one covering work on mixed-vapor adsorption by A. C. Zettlemoyer of the department of chemistry, Lehigh University, Bethlehem, Pa., for \$6,200, and one on thermal conductivity of liquids and solutions as a function of temperature by J. Coates of the department of chemical engineering, Louisiana State University, Baton Rouge, La., for \$13,800.

By far the larger portion of the \$1,045,000 was devoted to research in the biological sciences, and some was allotted to the support of studies and conferences on science, scientific information exchange, compilation of scientific personnel information, education in the sciences, and the travel of American scientists to international scientific meetings.

## CHEMICAL ENGINEERING GRANTS BY ETHYL CORP.

Nine research programs in chemical engineering are being supported for 1953-54 by the Ethyl Corp., according to a recent announcement. The institutions at which the work is being carried out are Cornell University, University of Illinois, University of Delaware, Iowa State College of Agriculture and Mechanical Arts, Louisiana State University, Ohio State University, Princeton University, University of Texas, and University of Tulsa.

Also included in the \$40,000 graduate fellowship program are four grants in mechanical engineering, seven in chemistry, and one in physics. These are in addition to special research projects supported at a number of universities.

## REFINERY OFFERS STAFF COURSES

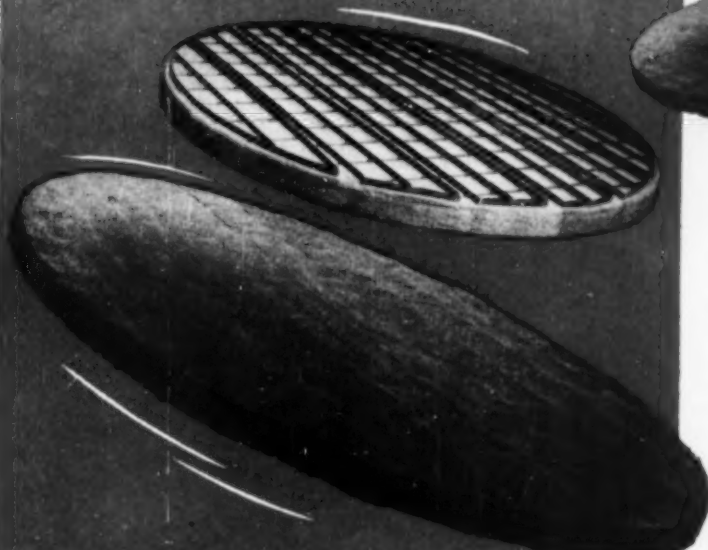
The Humble Oil & Refining Co. in its eighth annual series of lectures for the technical and research staff invited a chemical engineering professor and four chemistry professors, one from Europe, to conduct two- or four-week courses at the Baytown Refinery this spring.

R. R. White of the department of chemical and metallurgical engineering, University of Michigan, dealt with scale-up of processes; T. J. G. Overbeek, on leave from the University of Utrecht, Holland, gave a course in emulsions; and F. H. Westheimer of the University of Chicago and F. A. Matsen and Norman Hackerman of the University of Texas will discuss the mechanics of organic chemical reactions, general physical chemistry, and corrosion and electrochemistry respectively.

(News continued on page 66)



# Get Improved Performance In Process Equipment by Clean Separation between Vapors and Liquids with YORKMESH DEMISTERS

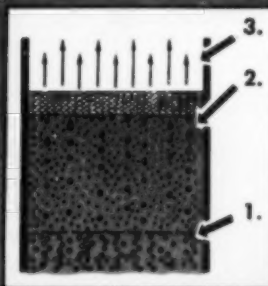


## How YORKMESH Demisters work inside Vacuum Towers

Vapor disengaging from liquid creates fine liquid droplets which are carried as entrainment by the vapor stream.

The liquid droplets impinge on the fine wire surfaces of YORKMESH, and are condensed into large drops which run down and fall off the YORKMESH.

The vapor is now dry. It has been entirely freed from entrained liquid. Thus a clean gas goes to the catalytic converter.



Yorkmesh Demisters are answering Chemical Engineers demands the world over for a simple means of improving the performance and increasing the capacities of process equipment handling vapor and liquid materials.

- Higher vapor velocities can be used.
- Overhead product quality is improved.
- Entrainment losses are eliminated.
- Overall operating efficiency is improved.
- Easily installed in existing or new equipment.

### For use in:

Vacuum towers  
Distillation equipment  
Absorbers  
Scrubbers  
Separators  
Evaporators  
Knock-out Drums, etc.

### Prompt shipment in:

Monel, Nickel  
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Carbon Steel  
Copper, Aluminum  
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Other Alloys

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Write for new Catalog 13  
for complete information  
and engineering data on  
YORKMESH Demisters.



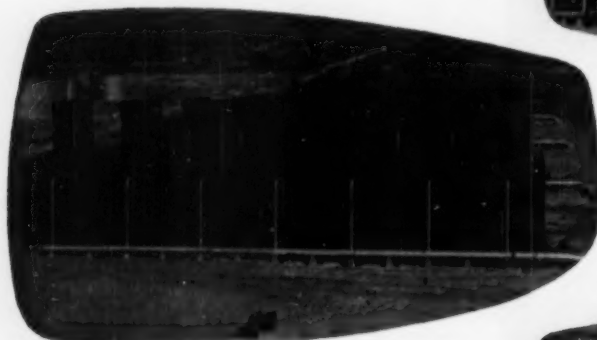
**OTTO H. YORK  
Co., Inc.**

73 Glenwood Place, East Orange, N. J.

**FLUOR** is building  
the world's largest initial  
cooling tower installation



These Fluor Counterflo Cooling Towers are now being erected in the San Fernando Valley at the site of the new 512,000 KW steam-electric generating plant for the Department of Water and Power, City of Los Angeles. They comprise the largest initial cooling water circulating system utilizing cooling towers ever built.



**T**he power plant itself is the largest initial installation inland and is being constructed in two sections. The first section consists of two units of 100,000 KW each, the second section of two units of 156,000 KW each. The four Fluor towers shown here (28 cells) in progressive stages of erection, are designed at 36,000 g.p.m. each, with a maximum of 42,000 g.p.m. They will service the first section of the plant. Design cooling range is 14° F with water entering at a temperature of 95° F and leaving at 81° F. The design wet bulb temperature is 70° F. Heat load is 1 billion B.t.u./Hr. for the first four towers.

Each cooling tower is 250 ft. long, 42 ft. wide and 37.5 ft. high to the fan deck. Twenty-foot, four-bladed fans are driven by 40 H.P. motors. Each fan moves 436,000 CFM. Capacity rating is 144,000 g.p.m. through a low pressure water distributing system. A distinctive feature of these towers is the Fluor-designed redwood stack standing 30 ft. high to minimize recirculation at peak load conditions.

Ground has been broken for the erection of four additional Fluor towers to serve the second section of the plant. Each tower will consist of 5 double-cells for a total of 40, with water circulation of 136,800 g.p.m. Design duty: inlet temperature 101° F, outlet 80° F, wet bulb 70° F. Heat load is 1,440,000,000 B.t.u./Hr. Dimension of these towers: 180 ft. long, 66 ft. wide, 45 ft. high to fan decks. Fans (18 ft.) will be driven by 40 HP motors and each will move approximately 350,000 CFM.



In addition, an auxiliary system (the bearing cooling water) employs a 4-cell Fluor Tower with a heat load of 40 million B.t.u./Hr.

When completed, total cooling water circulation will exceed 280,000 g.p.m. and will circulate over 240 miles of condenser copper tubing. Total heat load will approach 2½ billion B.t.u./Hr. The big jobs can be entrusted to Fluor, a firm with 33 years experience in the design and manufacture of cooling towers for every type of service. For complete details on Fluor Cooling Towers, write for the new illustrated bulletin, "Cooling Water for Industry."



BE SURE WITH

**FLUOR**

THE FLUOR CORPORATION, LTD.  
LOS ANGELES 22, CALIFORNIA

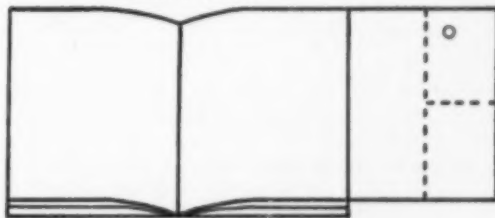
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This C.E.P. information service is a convenient way to get the chemical engineering information you need on the new equipment, on advertised products, on the newly announced developments reported on these pages. A one post card inquiry designed to bring data quickly and easily. Circle the items of interest, sign your name, position, address, etc., and drop in the mail.

Just a moment is needed to learn how to use this insert. When looking through the front part of the magazine pull the folded portion of the insert out to the right, and the numbers on the post card are convenient for marking. THEN . . .



as you pass the pull-out page, and it is on the left, fold the post card back along the vertical scoring, and once again the numbers are handy for circling.



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**CHEMICAL ENGINEERING PROGRESS**

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New York 17,

New York

**CHEMICAL ENGINEERING PROGRESS**

120 East 41st Street

New York 17,

New York

14

34

41

51

71

71

81

81

101

111

121

131

141

151

161

161

171

171

## PRODUCTS

- 1FC Activated Carbon**  
For all gas and vapor adsorption applications.  
Carbide and Carbon Chemicals Co.
- 3R Rotary Sifter**  
Constructed for continuous operation in grading or sifting of dry chemicals.  
B. F. Gump Co.
- 4L McLeod Gauges**  
For measuring low pressures of gases. Used in vacuum distillation, vacuum tubes, vacuum drying equipment.  
Ace Glass, Inc.
- 5A Aluminum Storage Tanks**  
Fabrication and field erection of tanks and pressure vessels.  
Nooter Corp.
- 6A Bar Stock Valves**  
Valves for spray process milk driers.  
Crane Co.
- 7A Chemical Porcelain**  
For lined equipment. Fiberglass woven cloth acts as a cushion against impact damage.  
Lepp Insulator Co., Inc.
- 8A Economic Studies**  
For process evaluation in the chemical field.  
Badger Manufacturing Co.
- 9A Ammonia Processing**  
Features nitrophosphate plant using continuous chemical processes in pelleted fertilizer.  
The Chemical and Industrial Corp.
- 10L Rupture Discs**  
Large stock in pressures from 5 to 50,000 lb.  
Black, Sivalls & Bryson, Inc.
- 11A Pressure Leaf Filters**  
Both vertical and horizontal. Rates up to 45,000 gal./hr.  
Niagara Filters Div., American Machine and Metals, Inc.
- 12A Celite Filtration**  
Filter powders for antibiotics, food products, chemicals, petroleum, etc.  
Johns-Manville
- 13A Evaporators**  
Designed, built and serviced by Buflovak.  
Buflovak Equipment Div. of Blaw-Knox Co.
- 14A Heat Exchangers**  
Installation sub-cools aniline after it has been condensed. Also expansion joints, traps, strainers, and separators.  
American District Steam Co., Inc.
- 15A Plastics Dryer**  
60 in. x 32 ft. 0 in. stainless steel dryer. Also steam jacketed batch dryer.  
The C. O. Bartlett & Snow Co.
- 16L Vertical Pumps**  
No submerged bearings. For pumping abrasive corrosive slurries.  
Lawrence Pumps, Inc.
- 17A Fans**  
Multi-blade aluminum fans for cooling tower applications.  
The Marley Co.
- 18A Pneumatic Transmitters**  
For measuring flow, pressure, level and density.  
Republic Flow Meters Co.
- 19A Petrochemical Processes**  
Design and construction of petrochemical process units and complete plants.  
Foster Wheeler Corp.
- 21A Sealless Pumps**  
No stuffing boxes, no lubrication. Available in 1/3, 1/2, 1, 2, and 3 horsepower sizes.  
Chempump Corp.
- 22L Pumps, Valves, Pipe and Fittings**  
Centrifugal pumps; globe, angle and Y valves; pipe and fittings.  
Vanton Pump & Equipment Corp.
- 23A Liquid Filters**  
Bronze fitted filters for water cooling systems.  
Dollinger Corp.
- 24A Dryers**  
Truck dryers, large multiple-unit tunnel dryers, single-apron conveyor dryers, and tunnel conveyor dryers.  
The National Drying Machinery Co.
- 25A Vacuum Pumps**  
Model V5M 556 theoretical displacement 13 cu.ft./min. at 450 rev./min.  
Kinney Mfg. Div., The New York Air Brake Co.
- 26L Line Blind Valves**  
Visible shut-off, easily visible from a distance.  
Hamer Oil Tool Co.
- 27A Graphite Electrodes, Anodes, Molds**  
Features chlorine for refrigerants and other cooling operations.  
Great Lakes Carbon Corp., Electrode Div.
- 28A Pressure or Vacuum Filtration**  
Features an Elmco precoat unit.  
The Elmco Corp.
- 29R Tefton-Jacketed Gaskets**  
For stainless steel, glass-lined steel and conical-flanged glass pipe. Also snap-on gaskets and adaptors.  
United States Gasket Co.
- 30A Centrifuges**  
For the continuous clarification of liquids containing solids, or the separation of two immiscible liquids.  
The Sharples Corp.
- 31A Stainless Tubing**  
Seamless or welded stainless tubing in any number of grades, in a broad size range.  
The Babcock & Wilcox Co., Tubular Products Div.
- 32A Chemical Pumps**  
Features nitric acid pump. Rated at 185 lb./min. against 400 lb./sq.in. maximum pressure. Several other types described.  
The Aldrich Pump Co.
- 33A Carbon Monoxide Plant**  
Designed and built by Girdler.  
The Girdler Co.
- 34A Glassed Steel Reactors**  
Resist attack by all acids except hydrofluoric.  
The Pfautler Co.



# Chemical Engineering Progress

Numbers followed by letters indicate advertisements, the number corresponding to the page carrying the ad. This is for ease in making an inquiry as you read the advertisements. Letters indicate position—L, left; R, right; T, top; B, bottom; A indicates a full page; IFC, IBC, and OBC are cover advertisements.

Be sure to give name, address, position, etc.

Remember, the numbers on the upper portion of the card bring you data on only the bulletins, equipment, services, and chemicals reported in these information insert pages. The lower portion of the card is for the advertised products, and is keyed not only to advertising pages, but also to the memory-tickling list under the heading Products.

- 110A Louisville Cooler**  
Surface coolers, water tube coolers, and atmospheric coolers.  
Louisville Drying Machinery Unit, General American Transportation Corp.
- 39A Saddle Packing**  
Features data on Intalox saddle packing.  
U. S. Stoneware Co.
- 40A Karbate Process Equipment**  
Features heat exchangers. Also pumps, towers, etc.  
National Carbon Co.
- 43R Flowmeters**  
Model 202 features differential pressure ranges from 20 in. WC to 400 in. WC. Pressures to 4,500 lb./sq.in. Static pressure pen is optional.  
Barton Instrument Corp.
- 44A Measuring and Controlling Equipment**  
Features control system for addition of caustic to phosphate flotation process.  
Minneapolis-Honeywell Regulator Co.
- 47A Nickel-Lined Pipe**  
For application in fields such as organic chemicals, caustic soda, pulp and paper, natural gas production, and water systems.  
The International Nickel Co., Inc.
- 48L Oil Reclaimer**  
Equipment for reclaiming, filtering, purifying and re-refining oil.  
The Hilliard Corp.

(Continued on back of this insert)

Please do not use this card after August, 1954

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
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## Advertisers' Products

IFC	3R	4L	5A	6A	7A	8A	9A	10L
11A	12A	13A	14A	15A	16L	17A	18A	19A
21A	22L	23A	24A	25A	26L	27A	28A	29R
30A	31A	32A	33A	34A	110A	39A	40A	43R
44A	47A	48L	49A	50L	51A	52A	61A	63A
64L	64R	65R	66L	67TR	67BL	67BR	68L	68TR
68BR	69R	70L	73R	75T	75B	76T	76B	77R
78T	78BL	78BR	79T	79B	81R	82T	82B	83B
IBC	OBC							

## Chemical Engineering Progress Data Service

Name .....

Position .....

Company .....

Address .....

City .....Zone .....State .....

☐ I want a subscription. Bill me \$6.00 for a year.

March, 1954

Please do not use this card after August, 1954

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## Advertisers' Products

IFC	3R	4L	5A	6A	7A	8A	9A	10L
11A	12A	13A	14A	15A	16L	17A	18A	19A
21A	22L	23A	24A	25A	26L	27A	28A	29R
30A	31A	32A	33A	34A	110A	39A	40A	43R
44A	47A	48L	49A	50L	51A	52A	61A	63A
64L	64R	65R	66L	67TR	67BL	67BR	68L	68TR
68BR	69R	70L	73R	75T	75B	76T	76B	77R
78T	78BL	78BR	79T	79B	81R	82T	82B	83B
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## Chemical Engineering Progress Data Service

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☐ I want a subscription. Bill me \$6.00 for a year.

March, 1954

## PRODUCTS (Continued)

- 49A Ion Exchange Resins**  
Resins remove ash from cane sirup solutions. Also for purification of gelatin, amino acids, fruit drinks, etc. Rohm & Haas Co.
- 50L Catalyst**  
For removal of carbon monoxide from hydrogen. The Girdler Co.
- 51A Yorkmesh Demisters**  
For improving the performance and increasing the capacities of process equipment handling vapor and liquid materials. Otto H. York Co., Inc.
- 52A Cooling Towers**  
Features world's largest initial cooling tower installation. Fluor Corp., Ltd.
- 61A Spray Dryers**  
Twenty-one recent Bowen spray dryer installations illustrated. Bowen Engineering, Inc.
- 63A Castings, Valves and Fittings**  
Stainless steel castings for corrosive operations. The Cooper Alloy Foundry Co.
- 64L Spray Nozzles**  
For chemical spraying, cooling, humidifying, and dehydrating. Binks Mfg. Co.
- 64R Mist Eliminator**  
Liquid carry-over controlled by separators made of knitted wire mesh. Metal Textile Corp.
- 65R Automatic Tank Gauging**  
For high and low pressures and all gauging requirements. The Vapor Recovery Systems Co.
- 66L High-Alloy Castings**  
Furnace rollers, heat treating trays, furnace shafts, annealing belts, reverts, and tubing. The Duraloy Co.
- 67TR Spray Nozzles**  
Catalog gives reference data on thousands of standard and special spray nozzles. Spraying Systems Co.
- 67BL Heat Exchanger Tube Ends**  
To increase tube life. Available in any length, diameter or gauge. Condenser Service & Engineering Co.
- 67BR Belt Conveyor Carrier**  
Welded steel frame, spun-end rollers made from a single piece of heavy gauge steel tubing. Available from stock. Stephens-Adamson Mfg. Co.
- 68L Industrial Work Clothing**  
Resists acids, alkalies, grease, dirt and oil. American Allsafe Co., Inc.
- 68TR Pilot Plant Engineering**  
Any of the unit chemical engineering processes from a crystallization to solvent recovery. Foster D. Snell, Inc.
- 68R Turbo-Dryers**  
Continuous, vertical, and transfer types. Wyssmont Co.
- 69R Mass and Paste Mixers**  
Heavy duty mixer illustrated. Direct drive, jacketed for temperature control. Paul O. Abbé, Inc.
- 70L Conical Mills**  
Sizes from 2 ft. to 10 ft. with capacities from a few pounds per hour to 100 tons per hour. Hardinge Co., Inc.
- 73R Junior Size Dryer**  
For pilot plants, laboratories and schools. 8 ft 10½ in. long, 7 ft. 6 in. wide, 7 ft. 1 in. high. C. G. Sargent's Sons Corp.
- 75T Agitator Drives**  
Double and triple reduction drive unit. Western Gear Works
- 75B Filter Presses**  
For practically any kind of filter material. D. R. Sperry & Co.
- 76T Grinders, Crushers**  
For small laboratory mills to high tonnage mills. Literature. American Pulverizer Co.
- 76B Diaphragm Pumps**  
For corrosive, abrasive and other difficult applications. T. Shriver & Co., Inc.
- 77R Antifoam**  
3 grams kill foam in 10 tons of asphalt or alkyd resin. Free sample. Dow Corning Corp.
- 78T Pumps**  
Horizontal and vertical shaft types in complete range of sizes. Nagle Pumps, Inc.
- 78BL Steam Jet Ejectors**  
Condensers and vacuum equipment. Corrosion resistant parts interchangeable with standard parts. The Jet-Vac Corp.
- 78BR Permanent Filter Media**  
For H<sub>2</sub>SO<sub>4</sub> fuming HNO<sub>3</sub>, caustic, etc. Micro Metallic Corp.
- 79T Pilot Plants to Processing Equipment**  
Manufacture of full range of chemical processing equipment. Artisan Metal Products, Inc.
- 79B Plasticizer Oil**  
Compatibility with GRS, neoprene, and buna N type rubbers. Pan American Refining Corp.
- 81R Industrial Equipment**  
Dust and fume control, spray booths, mechanical washers, and industrial ovens. Schmieg Industries, Inc.
- 82T Surface Pyrometer**  
For plant and laboratory surface and subsurface temperature measurements. Selection of thermocouples and extension arms. Pyrometer Instrument Co.

## PRODUCTS (Continued)

- 82B Plate Fabrication**  
Towers, pressure vessels, general plate fabrication and heat exchangers.  
Downingtown Iron Works, Inc.
- 83B Evactors**  
Steam jet vacuum units provide pressures ranging from a few inches to a few microns.  
Croll-Reynolds Co., Inc.
- IBC Controlled Volume Pumps**  
Features pump with capacity range from 1 pint to 2,700 gal./hr.  
Milton Roy Co.
- OBC Pilot Plant Mixers**  
Also description of "Lightnin" mixers of all sizes.  
Mixing Equipment Co., Inc.

## CHEMICALS

- 1 Ansol Chemicals.** Booklet on complete line of Ansol Chemical Co. products. Materials available in commercial & pilot plant quantities. Formulae given.
- 2 Ethyl Silicates.** Commercial grades of ethyl silicates listed in a 6-page technical bulletin from Carbide and Carbon Chemicals Co. A new use is with lubricants for extruded clay forms.
- 3 Organic Chemicals.** Eleven new organic chemicals have been added to Eastman Kodak Co. line. Included is tetrabromophenolphthalein-ethyl-ester acid-base indicator used in titrations in anhydrous organic solvents.
- 4 Mois-Tec RG.** A new type of reagent which indicates 0 to 50 mg. of water in sample of 5 g. or less. Action is based on color change from deep purple to light pink for cobalt salts in presence of water. Data sheet. R. P. Cargille Laboratories, Inc.
- 5 Plasticizing Polyol.** Atlas Power Co. G-2401 is 85% aqueous solution of technical hydroxypropyl sorbitol. Hygroscopic & noncrystallizing. Useful in conditioning glues, toothpastes, tobacco, cellulose, etc. Technical bulletin.
- 6 Cabflex.** Godfrey L. Cabot, Inc. Cabflex ODP (iso-octyl-decyl phthalate) & Cabflex ODA (iso-octyl decyl adipate). Low volatility offers improved flexibility permanence in vinyl compounds.
- 7 Fumaric Acid.** Typical reactions of fumaric acid as well as properties of its products abstracted in technical bulletin from Monsanto Chemical Co. Applicable in paints, paper coatings, rubber plastics.
- 8 Surfactants.** Comprehensive 74-page brochure from Atlas Powder Co. General industrial applications. Covers polishes, petroleum products, cleaners & sanitizers. Diverse uses.
- 9 Urea.** Montecatini's unique ammonia-saturated process for production of urea is subject of booklet from M. W. Kellogg Co., exclusive licensor of process in the United States.
- 10 Vinyl Resin.** A dry blending grade of vinyl resin added to Pliovic line of polyvinyl chloride resins by Goodyear Tire & Rubber Co. Aids plastic molders in obtaining free-flowing dry mix without high heat & long mill cycles.

## BULLETINS

- 15 Heat Exchangers.** Engineered to meet individual requirements. Made of ferrous & nonferrous materials. Doyle & Roth Mfg. Co., Inc.
- 16 Controlled Closing Valves.** Prevention of hammer damage when filling pipe lines, control over speed of closure, & protection against pipe collapse accomplished by Type CCAV valves. Brochure. Simplex Valve & Meter Co.
- 17 Precipitator.** Booklet describes solution precipitator which removes impurities from a liquid by precipitations, adsorption, settling & filtration. Permutit Co.
- 18 Roller-Type Hold-Back.** Prevents reversal of bucket elevators & inclined conveyors because of power failure. Standard Products Division, Stephens-Adamson Mfg. Co.
- 19 Relief Valve.** Bulletin describes pilot-operated valves sizes 1/4 to 3/4 in. For temperature range from -650° F. to +160° F. Pressures from 350 to 5,000 lb./sq.in. Pantex Mfg. Corp.
- 20 Conveyor Belt Cleaning Brushes.** Mounted from the belt itself. Technical data sheet. Industrial Division of Fuller Brush Co.
- 21 HCl Absorbers.** Impervious graphite. Illustrated catalog shows schematic diagrams, gives table of six standard sizes. Falls Industries, Inc.
- 22 Automatic Production Control.** A 24-page booklet describes available controls. Reeves Pulley Co.
- 23 Solenoid Valves.** Loose-leaf catalog No. 24 on solenoid valves includes selection & flow charts, index to available technical bulletins, other data. Automatic Switch Co.
- 24 Precision Molding & Extrusion.** Facilities are described for Kel-F, Teflon & nylon. Flek Corp.
- 25 Spray Nozzles.** A complete reference catalog describing thousands of standard & special industrial models. Spraying Systems Co.
- 26 Close-Coupled Pumps.** Leaflet describing motor pumps for filter service. Shows performance curves. Sizes 1/4 through 50 hp.; 200 models. Ingersoll-Rand Co.
- 27 Motors.** Bulletin compares methods for lubrication of electric motors. U. S. Electrical Motors, Inc.
- 28 Transmission Equipment.** Couplings, pulleys, transmission, universal joints covered in recent binder insert. Lovejoy Flexible Coupling Co.
- 29 Freeze Drying.** Brochure is a compendium of principles, methods & benefits of this process. F. J. Stokes Machine Co.
- 30 Fiberglass Insulations.** Brochure describes industrial insulations for use at temperatures from sub-zero to 1200° F. Owens-Corning Fiberglass Corp.
- 31 Dehydration Units.** Bulletin. Afford protection of precision instruments & controls. J. F. Pritchard & Co.
- 32 Plating Anodes.** Illustrated catalog of sizes, shapes, compositions, other characteristics facilitates selection of proper anode. Federated Metals Division, American Smelting and Refining Co.
- 33 High Vacuum Apparatus.** Revised & expanded catalog. Several pages of factual data on planning a high vacuum system. Central Scientific Co.

- 34 **Air Preheater.** Ljungstrom air preheater reduces fuel consumption by approximately 30%. Discussed in booklet. Tables of operating data, photographs & diagram. Air Preheater Corp.
- 35 **Cycleflow Valve.** A four-position single-control valve for control of flow through ion-exchange equipment. Operation to 250° F. American Water Softener Co.
- 36 **Industrial Mixers.** Folder from Conn and Co. Sizes ¼ to 100 hp. Alloy or steel construction.
- 38 (38) Two-page specification sheet on pressure balanced diaphragm motor valves. (39) Bulletin on measuring & controlling liquid level. Both from Minneapolis-Honeywell Regulator Co.
- 40 **Hot-Water Storage Heater.** All types described & illustrated in catalog from Patterson-Kelley Co., Inc.
- 41 **Titeflex Bellows.** Can be used as expansion connections for lines conveying gases & liquids undergoing temperature extremes, vibration & corrosion. Titeflex, Inc.
- 42 **Chemical Pumps.** Simplex & duplex reciprocating plunger pumps for pressures to 20,000 lb. & capacities from a few cc./min. to more than 900 gal./hr. illustrated & described in bulletin. Philadelphia Pump and Machinery Co.
- 43 **Sump Pumps.** Johnston Pump Co. Illustrated bulletin on unit-line sump pumps. Provide economy of packaged line with inherent advantages of engineered vertical turbine.
- 44 **Tanks, Mixers, Filters, & Pumps.** Alsop Engineering Corp. Opens or closed tanks; portable, top- & side-entering mixers; filters; pumps. Illustrated bulletin gives all pertinent data.
- 45 **Labline Kit.** For efficient planning of new laboratories or additions to existing ones, Labline, Inc. offers kit of twenty-six scaled three-dimensional models. Includes ruled layout sheets scaled ½ in./ft.
- 46 **Electrical Measuring Instruments.** Illustrated bulletin from Central Scientific Co. Includes electronic electrometers & relays; audio frequency oscillators; potentiometers.
- 47 **Molded O-Rings.** O-Rings of Teflon now being molded by Sparta Heat Treat Co. Not all sizes presently available. For use in temperature range -320° F. to 500° F.
- 48 **Glass Pipe & Fittings.** Pyrex brand glass tubing & small diameter glass pipe together with special fittings available from Sentinel Glass Co. Folder also describes corosilicate glass having low coefficient of expansion, thermal shock, & corrosion resistance.
- 49 **Heaters—Steam Generators.** A complete line of tank car heaters, units for pile driving, ready mix concrete plants, cold weather construction operations, etc. from Cleaver-Brooks Co. Specifications, ratings, etc.
- 50 **Synchronous Motors.** Constant speed synchronous motors & condensers are described in binder section catalog from General Electric Co. Provides cutaway views, details of construction, operation, covers problems common to application.
- 51 **Roto-Pulper.** A vertical single disc refiner featuring rotating 28-in. diam. disc mounted on vertical shaft. Equipped with replaceable plates. Illustrated folder gives complete descriptive information. Jackson & Church Co.
- 52 **Tall Oil.** Methods of refining & testing derivatives, materials of storage & processing equipment are described & discussed in booklet from K. A. Steel Chemicals, Inc. Applications include water soluble soaps, sulfonated tall oils, nonionic detergents.
- 53 **Gauge Saver.** Automatic shut-off valves for overload protection of gauges & instruments in hydraulic or pneumatic systems. Pressure ranges from 10 to 5,000 lb./sq.in. Bulletin lists features, specifications, adjustment & installation details. Sprague Engineering & Sales Corp.
- 54 **Temperature Control Systems.** Wheelco Instruments Div. educational bulletin. Sections on selecting sensing elements control terminology; selecting temperature-control method according to process characteristics.
- 55 **Pipe Data Card.** Designed to assist those who select, apply, & install carbon, alloy & stainless steel pipe. TDC 138 A new data card from Tubular Products Div., Babcock & Wilcox Co.
- 56 **Flexible Metal Hose.** Illustrated catalog on all types of metal hose by Flexonics Corp. Featured is industrial heavy-duty stainless steel hose, couplings & installation data.
- 57 **Air Flow & Liquid Level Control.** Punched, loose-leaf binder sheets on Detect-A-Flo, a device which has no moving parts, is hermetically sealed & installed directly in tank or air stream being monitored. Fenwal, Inc.
- 58 **High Vacuum Pumps.** Precision built, compound pumps of rotary vane design; free air capacities 0.75 to 30.0 cu.ft./min.; ultimate vacuum 0.50μ; automatic lubrication. International Pump and Machine Works.
- 59 **Electronic Controls.** New edition of "Cutting Production Costs with Electronic Controls," handbook. Reports on 46 applications of standard packaged electronic controls to problems of weighing, counting, measuring, timing, & cycling. Photoswitch Corp.
- 60 **Paint Leaflet.** Carboline Co. Binder sheet on basic economy of paint for corrosion protection. Chart correlates probability of early failure with film thickness.
- 61 **Instrument Printing Systems.** A 30-page loose-leaf catalog describes devices for transducing, storing, & printing data. Electrical Development Co., Inc.
- 62 **Filters.** Continuous & batch vacuum pressure filters, also acid handling & slurry pumps. Oliver United Filters Inc. illustrated bulletin describes all types in wide variety of corrosion-resistant materials.
- 63 **Humidity Control.** New issue of "The Humidity Engineer" from Surface Combustion Corp. contains practical articles on application of humidity conditioning.
- 64 **Froth Flotation.** Separation of near-colloidal size particles from saturated brine; fractionation of fine clays; recovery of fossil resin from coal; water purification, etc. are subjects of bulletin from Denver Equipment Co.
- 65 **Neovane Pumps.** Rubber impeller pumps manufactured by Lee Healey Co. Exclusive tapered elliptical-shaped impeller. For use between 0° F. to 175° F. & for fine solids. Three sizes.

## EQUIPMENT

- 70 **Transducer.** Foxboro Co. Dynaformer pressure cell converts fluid pressure into proportional a-c voltage signal then converts to pressure indication. Accurate to  $\pm 1/4\%$ .
- 71 **Apron Conveyors.** Three types of new piano-hinged apron conveyors, suited for conveying objects ranging from containers to flakes. Pans in widths of 12 to 48 in. Link-Belt Co.



- 72 **Corrosion-Resistant Tape.** For protection of conduit joints where corrosive fumes are a problem. Fuses into solid mass after application. Bishop Mfg. Corp.
- 73 **Conveyor Belt Cover.** Adds resistance to abrasion not previously attained. Applicable to wide range of belts. Raybestos-Manhattan, Inc.
- 74 **Rotary Joints.** New type packless & leakproof rotary joints operates on ball & socket principle. Key Co.
- 75 **Mercury Rectifier Speed Controller.** Variable-voltage mercury rectifier controls d-c power drive equipment from a-c source. Reliance Electric & Engineering Co.
- 76 **Thermocouple Well.** Metal-ceramic thermocouple well. A bulletin outlines properties & specifications of new product line. Bristol Co.

- 87 **Plastic Gloves.** All vinyl plastic gloves molded from unsupported polyvinyl film for handling acids, alkalis, & resins. Houghton Laboratories, Inc.
- 88 **Laboratory Ovens.** Isotemp uniform temperature ovens by Fisher Scientific Co. for research, testing, & quality control.
- 89 **Separators.** Single- & multiple-deck screens described in illustrated bulletin from SWECO Separator div. Southwestern Engineering Co.
- 90 **Explosion Chamber.** Tenney Engineering, Inc. bulletin describes chamber for use in determining effect of explosion on materials, components; also to determine if equipment will ignite in explosive atmosphere. Simulated altitude conditions optional.

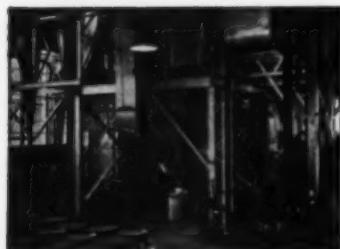
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- 77 **Conveyor Scale.** Transportometer weighing scale for use on new or existing belt-conveyor installations, where overhead clearance is limited. Sintering Machinery Corp.
- 78 **Glassed Steel Packed Column.** Standardized glassed steel packed column for severe chemical processing service conditions. Interchangeable parts. Pfafflader Co.
- 79 **Portable Instrument Calibrator.** Pneumatic calibrator for testing & calibrating pressure instruments operating from 20 in. H<sub>2</sub>O to 25 lb./sq.in. Republic Flow Meters Co.
- 80 (80) Mechanical rectifier unit substation. Provides d-c
- 81 power. (81) An electropolarizer complete with portable galvanometer, which aids in chemical analysis of plating solutions. General Electric Co.
- 82 **Electronic Air-Cleaning Unit.** A low-cost electronic air-cleaning unit called Precipitron. Westinghouse Electric Corp.
- 83 **Liquid Level Control.** A 35-page loose-leaf binder on liquid-level control; covers service, schematic drawings. Techniflex Corp.
- 84 **Wobble-Rod Air Valve.** Bulletin describing details of wobble-rod on-off control air valve from Pantex Mfg. Corp.
- 85 **Deionizer.** Cartridge-type deionizer to produce solids-free water at rate of 5 gal./hr. Illinois Water Treatment Co. Two models available — one comparable to triple, & the other to single distilled.
- 86 **Vibration Isolator.** Series 262 & 633 vibration isolators from Barry Corp. announced in illustrated product bulletin. For motors or motor-driven equipment.

- 91 **Boiler-Burner Units.** Catalog from Kewanee-Ross Corp. describes new boiler-burner units featuring 8.2 sq.ft. of heating surface/boiler horsepower, certified efficiency of 80%.
- 92 **Slide Chart.** Available from Lebanon Steel Foundry, slide chart giving data on steel casting material selection. Reference data on 19 carbon & low alloy grades & 17 stainless & corrosion-resistant grades produced. Gives comparable ACl, AISI, ASTM, SAE, other designation where applicable.
- 93 **Signal Transmitter.** Now available with specially designed pneumatic signal transmitter is Hagan Corp. ring balance meter. Pressure ranges 15, 30, 60 lb./sq.in.
- 94 **Voltmeter.** From Trio Laboratories a miniature panel-mounting vacuum-tube voltmeter. Requires only as much panel area as standard 3½ in. meter. Depth only 4¼ in.
- 95 **Clear Sheet.** Homalite CR-39 a clear, transparent, scratch- & abrasion-resistant thermosetting resin sheet material. Folder covers recommended applications. Homalite Corp.
- 96 **Pipe Insulation.** Mono-Kover, lightweight, one-piece pipe insulation. Bulletin describes application, properties. Includes chart on thermal efficiency, thickness selection, sizes. Baldwin-Hill Co.
- 97 **Filter Fabric.** New cloth of woven polyethylene monofilaments developed by Filtration Fabrics div. of Filtration Engineers, Inc. Relatively open mesh, recommended for free-filtering applications such as coarse crystalline materials or fibrous pulps.
- 98 **Rubberchem Pump.** Eco Engineering Co. stainless steel & Teflon All-Chem pump. For corrosive fluids & capacities to 10 gal./min. & 100 lb./sq.in. for sustained service. Self-priming.

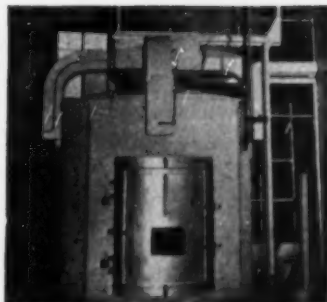
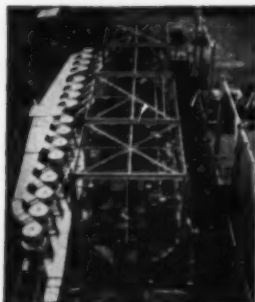
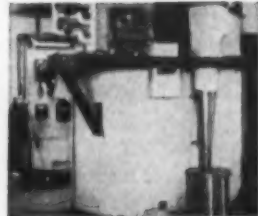
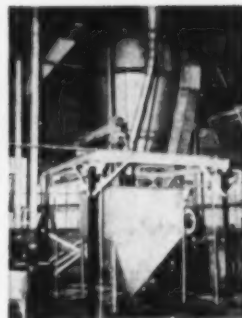
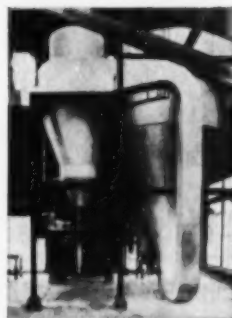
- 99 **Switch Enclosures.** Lead-plated, sheet-steel enclosures for safety switches & circuit breakers announced by Trumbull Components dept. of General Electric Co. Designed for outdoor use & special corrosive applications.
- 100 **Pouring Spout.** General Scientific Equipment Co. type 50 spout fits bottle openings from 1 to 1 3/8 in. Made of acid-resistant rubber & plastic tubing.
- 101 **Warning System.** Magnalarm completely automatic alarm system for magnetic separators by Eriez Mfg. Co. Eliminates human error.
- 102 (102) **Oxweld NA-7** acetylene generator delivers at constant output pressure of 8 to 13 lb./sq.in. Linde Air products div., Union Carbide and Carbon Corp. (103) **Special carbide screw elevator** for recharging large, double-hopper acetylene generators. Feeds 3/8 in. or smaller particles to receiving hopper at rate of 200 lb./min.
- 104 **Plug Valves.** Hamer Oil Tool Co. announce new 10- & 12-inch plug valves produced in A.S.A. 150# & 300# classes, available in carbon steel and other materials for refinery & general service involving temperature extremes. Packings are replaceable under pressure & while on stream.
- 105 **Pressure Transducer.** Model DP-7 sensitive pressure transducer from North American Instruments, Inc., measures differential pressure in terms of electrical output. Working fluids include all noncorrosive gases & liquids. Design allows working ranges from  $\pm 0.5$  to  $\pm 15$  lb./sq.in. differential at pressures to 100 lb./sq.in.
- 106 **Pressure Gauge.** Designers for Industry offers new design pressure gauge for oil and refinery and general industrial applications. Available with dial diameter of 1 in.; total weight less than 2 oz. Pressures 0 to 100 up to 0 to 60,000 graduation readings.
- 107 **Portable Fume Washer.** Folder from U. S. Stoneware Co. on Cyclonair, a portable fume washer for low-cost fume removal in plants & laboratories, gives complete technical data, performance charts, drawings, etc.
- 108 **Lab Blender.** Small-scale laboratory twin-shell blender, yoke model mounted in standard 4- & 8-qt. frame. Shells are heavy Lucite. Load capacities 1, 2 & 4 pints. Dust- & watertight, quick-opening cover plates for easy cleaning. Patterson-Kelley Co., Inc.
- 109 **Controlled-Volume Pumps.** Mersemetric, new Milton Roy Co. controlled volume pump without diaphragm or open seal, is completely submerged in liquid being pumped. No external leakage; flow control; available in variety of materials. Bulletin.
- 110 **Homogenizer.** High-pressure portable laboratory homogenizer, with complete separation of product from drive mechanism. Removable head for autoclaving. Pressures 0 to 3,000 lb./sq.in. Processes quantities from 1 cc. to 25 gal./hr. No packing or stuffing boxes. Self-priming. C. W. Logeman Co.
- 111 **Moisture Meter.** From Heyl & Patterson an accurate, portable moisture meter called Olivo. Easily operated, accurate to 2% of surface moisture, determines content in less than 2 min.
- 112 **Heat Exchangers.** Line of pressure heat exchangers for passing corrosive liquids or gases under pressure & high temperature through tubes or shell. Molded from Havg, an acid-digested asbestos bonded with synthetic resins. Long life, corrosion resistant. Pressures from 50 to 75 lb./sq.in. & temperatures to 265° F. Havg Corp.
- 114 **Air Classifier.** For use in continuous separation of coarse & fine air-borne particles, new dry classifier, Gyrotor, from Hardinge Co., Inc. Illustrated bulletin gives applications, other pertinent data.
- 115 **Vibro-Mixer.** Designed to add power & versatility to closed-system mixing in laboratory, Vibro-Mixer is from Fisher Scientific Co. Selection of nine different stirrers & plates. Said to achieve complete interfacial mixing without vortex or stratification. Strokes of 0.2 to 2 mm.
- 116 **Depressurizing Safety Valve.** Designed to rapidly depressurize pressure vessels in emergency & to function as unloader where unloading is combined with safety valve. Variety of uses. Available sizes 1 x 1 1/2 in. to 2 1/2 x 4 in. Also 3 x 4 in. to 8 x 10 in. Farris Engineering Corp.
- 117 **Control Valves.** Series LB line of control valves. New concept of valve topworks in control industry. Coupled with single seated, split-body valve design. Sizes to 4 in. Illustrated catalog. Conoflow Corp.
- 118 **Pulverizers.** Screen hammer-type pulverizers called Ray-Ducer available from Raymond Division of Combustion Engineering, Inc. Units come in three sizes. Suitable for medium fine grinding of soft materials—foods, dry colors, filter cake, chemicals, etc. Compact but easily accessible for screen change, maintenance, inspection. Bulletin.
- 119 **Teflon Seal Cage.** One-piece Teflon seal cage developed by Chemical & Power Products, Inc., for use with stuffing boxes on pumps, mixers, reactors, other process equipment. Machined in one piece, easily snapped over shaft without dismantling pump or pulling shaft. Longer life than metal rings. Sizes for any pump, mixer, or agitator.
- 120 **Neoprene Tank Lining.** Special formulation eliminates 10 to 20 coat systems of tank lining with neoprene. Brush coats 10 to 20 mils may be applied so that 1/16 in. linings are obtained with 4 to 7 coats. Binder page gives corrosion-resistance chart, other data. For pharmaceutical, chemical processes, other industries. Carboline Co.
- 121 **Flow Alarm.** Flo-Gard meets demand for fail-safe sensitive alarm device for rotameters, manometers, other process instruments to provide dependable operating stability. Wide sensitivity range for both high & low flow. May be used with spherical floats of 3/32 in. Illustrated bulletin gives additional details. Brooks Rotameter Co.
- 122 **Automatic Controls.** Type Y continuously connected side handwheel for emergency manual control developed by Black, Sivalls & Bryson, Inc. For use with all their diaphragm-control valves. Operates on emergency basis. Screw is of nongalling 18-8 stainless steel with high-tensile aluminum-bronze nut for transmission of power through cast steel fork to valve stem.
- 123 **Quick Detachable Air Connections.** Said to provide almost complete free flow of air to air-powered tools; compact; quick detachable air connection. Binks Mfg. Co. recommend connection for air hose coupling on paint spray guns, etc. Full 360° swivel action. Bulletin.
- 124 **Packaged Detergent Plant.** Completely engineered synthetic-detergent plant, capable of producing finished spray dried product from basic raw materials available from Hull Co., division of Foster D. Snell Research, Inc. Unit includes sulfonation, neutralization, compounding, spray-drying equipment. Piping precut, marked for rapid, easy assembly. Four sizes.



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# MARGINAL NOTES

News of Books of Interest to Chemical Engineers

## For the Testing Time

**Measurement Techniques in Mechanical Engineering.** R. J. Sweeney. John Wiley & Sons, Inc., New York (1953), 309 pp. \$5.50.

*Reviewed by Joseph D. Stett, Chairman, Department of Mechanical Engineering, Rutgers University, New Brunswick, N. J.*

This is an excellent, comprehensive descriptive text dealing with measurement techniques such as may be used in many laboratory tests not only by mechanical engineers as the title indicates, but also by chemical engineers. It can serve in the selection of proper measurement instruments and common techniques in performance tests on power equipment such as engines, pumps, compressors, heat transfer, and combustion apparatus.

The book delves into the principles involved in the design of measuring equipment and includes excellent discussion of precautions and drawbacks of the methods as well as the advantages. The material is divided into sections dealing with test equipment and techniques in such broad areas as time and speed, electrical measurements, dynamometers, pressure, temperature, fluid flow, calorimetry, chemical analysis (gas, water and coal) and automatic controls. For those involved in general testing, maintenance or trouble shooting, this book can serve as a valuable guide or reference.

## Pests and Poisons

**Hanna's Handbook of Agricultural Chemicals.** Lester W. Hanna. West Coast Printing and Binding Co., Portland, Ore. (1953), xvi + 209 pp. \$3.25.

*Reviewed by P. H. Groggins, Food Machinery & Chemical Corp., Washington, D. C.*

This handbook is a pocket-size volume, which could conveniently be used by fieldmen in many of the agricultural sciences. It gives the various common and chemical names of more than 500 commercial chemicals used as fertilizers, soil conditioners, fumigants, fungicides, insecticides, herbicides and rodenticides.

Of particular interest to workers making or using agricultural chemicals are the sections and comments dealing with the toxicity of pesticides and the anti-

dotes that may be employed in case of poisoning.

The bulk of the volume is devoted to pesticides, a field in which the author has long worked. The information on such chemicals is concise and generally reliable. It would have been most helpful to have chapter or section introductions which surveyed the various fields. Such a summary would be particularly helpful in the chapters dealing with fumigants, insecticides and fungicides. It would be an aid in interrelating the numerous individual compounds as well as putting them in their proper perspective.

The chapter dealing with fertilizers is in general poorly presented and fails to come up to standards desired by chemists or chemical engineers. The following are some examples of hasty proofreading:

Methanol is not synonymous with formaldehyde.

Specific gravity of carbon tetrachloride is not 5.31.

This (NH<sub>3</sub>) is burned or oxidized with air and nitric acid.

Because the pesticide industry is a rapidly growing and important industry, the handbook should serve as a convenient source of ready information for entomologists, plant pathologists and agronomists. Managerial personnel responsible for avoiding or combating economic poison hazards will also find the volume useful.

## A Little Knowledge Is . . . Helpful

**Experimental Nuclear Physics, Vol. II.** E. Segré, Editor (contributors P. Morrison and B. T. Feld) John Wiley & Sons, Inc., New York (1953), 600 pp. \$12.00.

*Reviewed by L. E. Brownell and J. V. Nehemias, Fission Products Lab., University of Michigan, Ann Arbor.*

This volume consists of two monographs—by Philip Morrison on nuclear reactions and by Bernard T. Feld on the neutron. Both show evidence of years of painstaking preparation; and lucidity of presentation is characteristic throughout each.

As Dr. Feld says on page 208: "This work . . . presupposes a knowledge of . . . nuclear physics as well as of its terminology." The engineer without a

fairly good basic understanding of the physics involved, and familiarity with the terminology, would indeed find this volume difficult reading. However, for the engineer with these prerequisites, who seeks a better understanding of experimental nuclear physics as preparation for attacking laboratory or reactor design problems, this volume is an ideal source. It is a remarkably complete, concise, easily followed presentation of a substantial body of knowledge and conceptual information.

A good index, an exhaustive bibliography, and extensive use of cross references render the book extremely useful as a reference book, and as a starting point for more intensive, specialized studies in nuclear physics.

## Words, Words, Words

**Metallurgical Dictionary.** J. G. Henderson, assisted by J. M. Barnes. Reinhold Publishing Corp., New York (1953), 396 pp. \$8.50.

The *Metallurgical Dictionary* includes strictly metallurgical terms, production terms, and some other words related to the subject. The definitions are not lengthy, many averaging about forty words. They are, on the whole, not too technical for readers in other fields nor too difficult for metal-trades workers with high school education; yet they include the essential information. *Impact test*, for example, is defined as "a test in which one or more blows are suddenly applied to a prepared specimen. The results are usually expressed in terms of foot-pounds of energy absorbed, or the number of blows of a given intensity required to break the specimen. *See also* Charpy impact; Izod impact." As this definition shows, the cross references are helpful.

Clarity is the most admirable feature of the work. Ever since Samuel Johnson defined *network* as "anything reticulated or decussated at equal distances with interstices between the intersections," there have been dictionary makers to glory in polysyllabic and difficult terms. Using their dictionaries involves looking up the jawbreakers of each definition only to find more unknown words. The reader faced by unfamiliar words which send him farther and farther afield, seldom succeeds in

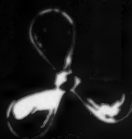
(Continued on page 64)



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## MARGINAL NOTES

(Continued from page 62)

discovering the meaning of the word he first looked up. Henderson and Bates have avoided such irritating definitions in spite of the problems involved in expressing clearly the meanings of difficult technical terms.

The explanations are unusually concise, although occasionally the technical reader may find that part of the meaning or a related meaning has been sacrificed to brevity. In such a case an older work such as Fay's *Glossary*, which includes the definitions of other writers, will be a necessary supplement.

For the chemical engineer who needs a metallurgical dictionary, the work of Henderson and Bates is suggested because it is up to date, clear, and concise. The chemical engineer who owns an older dictionary will find this new one useful if he needs definitions of modern terms such as *flame plating* or *shell molding* or if he wants simple explanations of older terms.

An appendix presents general discussion of steels, iron, aluminum, copper, lead, nickel, and zinc, with particular emphasis on production.

—H. J. TICHY

### A Bloodless Revolution

**The Chemical Revolution. A Contribution to Social Technology.** Archibald and Nan L. Clow. The Blatchworth Press, London (1952, xvi + 680 pp. 50 shillings, net. British Book Centre, Inc., New York 22, \$10.00.

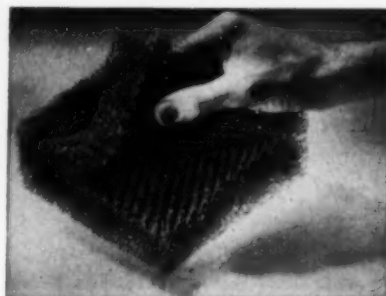
Reviewed by D. H. Killeffer, Consultant, Tuckahoe, N. Y.

This book is one of the kind of scholarly treatises that the British seem to do far better than we do this side of the Atlantic. The Clows here have attempted (and quite successfully) to show the chemical industry passing through the period of fundamental change that we call the industrial revolution. They have done this by gathering together great numbers of original documents to demonstrate how chemical industry went through the great metamorphosis from the crude "cottage" manufacture, that represents its beginnings and early history, to become an integrated part of our industrial and economic structure. Because of the manifest care that the authors have exercised in assembling and collating original materials, their book assumes an important place in this reader's library as a source book for chemical beginnings in England and Europe. While the individual chapters are fascinating to read as presenting the beginnings and development of the chemical craft, the book as a whole is likely to be more useful for

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reference than as a volume to be read through. A good usable index and copious references (for the benefit of scholars and skeptics) make the vast amount of material here readily available. In manuscript, the book was awarded the Senior Hume-Brown Prize of the University of Edinburgh.

**Inorganic Synthesis, Vol. IV.** John C. Bailar, Jr., Editor in Chief. McGraw-Hill Book Co., New York (1953), 218 pp. \$5.00.

*Reviewed by Paul D. V. Manning, Jr., Stearns-Roger Mfg. Co., Denver, Colo.*

This book is the fourth in a series describing methods of preparation for various inorganic compounds. The procedures described have all been checked and sometimes revised by various university and industrial laboratories.

The text contains a clear quantitative description of procedures used to produce about seventy inorganic compounds. Included are sketches of any special equipment that is required, the properties of each compound and, if necessary, the safety precautions to be taken. The treatment given each compound is dependent upon the complexity of the operation.

Two indexes are provided and each is cumulative: one is a subject index and the other a formula index. In addition there is an excellent reference list following the discussion of each compound.

"Inorganic Synthesis" continues the policies and practices of the previous volumes. It should prove just as valuable to the chemist or chemical engineer concerned with the use or production of such compounds as Volumes I, II, and III.

### Books Received

**Practical Chromatography,** R. C. Brimley and F. C. Barrett. Reinhold Publishing Corp., New York (1953), 128 pp. \$5.00.

**Procedures in Experimental Metallurgy.** A. U. Seybolt and J. E. Burke. John Wiley & Sons, Inc., New York (1953), xi + 340 pp. \$7.00.

**Industrial Inorganic Analysis.** Roland S. Young. John Wiley & Sons, Inc., New York (1953), viii + 368 pp. \$5.75.

**Microwave Spectroscopy.** M. W. P. Strandberg. John Wiley & Sons, Inc., New York (1954), 140 pp. \$2.50.

**Quantitative Organic Analysis via Functional Groups.** 2nd ed. Sidney Siggia. John Wiley & Sons, Inc., New York (1954), 227 pp. \$5.00.

**Organic Chemistry — A Brief Course.** R. W. Getchell. McGraw-Hill Book Co., Inc., New York (1954), 278 pp. \$4.00.



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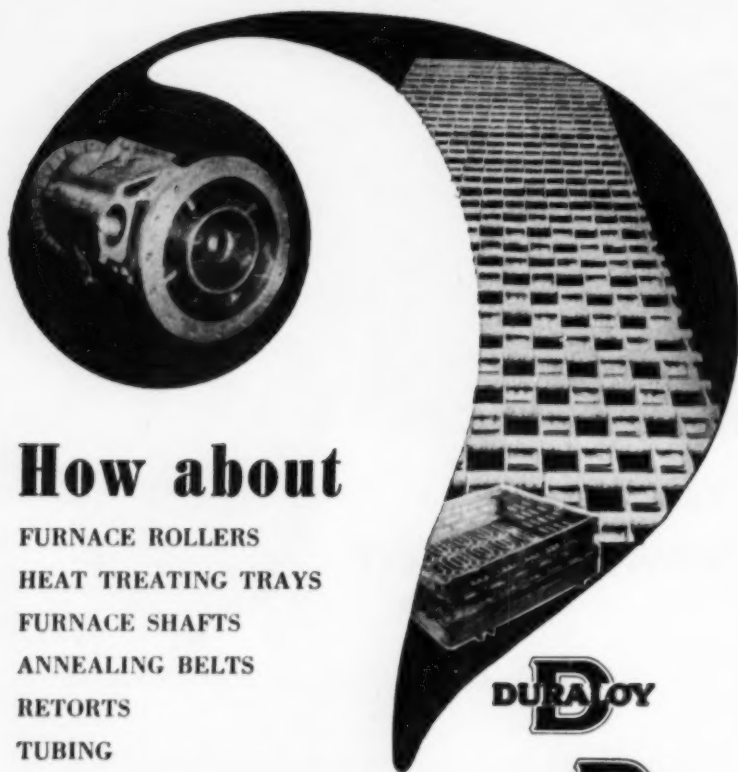
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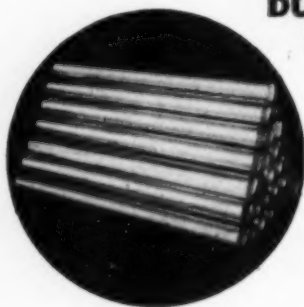
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## NEWS

(Continued from page 50)

### HONORARY SOCIETY ANNOUNCES OFFICERS

Phi Lambda Upsilon, honorary chemical society, announced recently the election of national officers for 1954-57. James M. Church of the department of chemical engineering, Columbia University, became national president; Carl S. Carlson, research director for the Morton Salt Co., Chicago, and a chemical engineer, was reelected vice-president; national secretary is Thomas B. Cameron of the department of chemistry, University of Cincinnati; William G. Schrenk, professor of chemistry at Kansas State College, is national treasurer, national editor is Milton Tamres of the department of chemistry, University of Michigan; and Albert H. Holtzinger of the department of chemistry, Pennsylvania State University, was reelected historian.

### GERMANS DEVELOP NEW SYNTHETIC WAXES

Pure waxes with high melting points are being developed by means of the Fischer-Tropsch process by the Krupp Kohlechemie G.m.b.H. of Germany. Marketed under the name SynPar, the waxes are high-molecular-weight aliphatic hydrocarbons containing some molecules branched with short side chains. Sales in this country are handled by H. L. Barnebey, P.O. Box 144, Pittsburgh 30, Pa.

### SAVE THOSE BACK ISSUES

Every so often an unprecedented demand for a particular issue, or an unexpected influx of new subscribers and members puts the editor in the embarrassing position of running out of copies of Chemical Engineering Progress. This has happened several times in our short history and if members have copies of any of the following issues, we would be glad to purchase them. The issues which we need and for which we will pay 75 cents each are: April, 1947, October and November, 1950, and February, 1953.

All these issues were overprinted to a great extent, but because of features and other demands, single copy sales, etc., they were completely exhausted in a short time.



## CANDIDATES FOR MEMBERSHIP IN A. I. Ch. E.

The following is a list of candidates for the designated grades of membership in A.I.Ch.E. recommended for election by the Committee on Admissions.

These names are listed in accordance with Article III, Section 7, of the Constitution of A.I.Ch.E.

Objections to the election of any of these candidates from Active members will receive careful consideration if received before April 15, 1954, at the Office of the Secretary, A.I.Ch.E., 120 East 41st Street, New York 17, N. Y.

### Applicants for Active Membership

Armstrong, Eldon L., Garden City, N. Y.

Armstrong, John C., New York, N. Y.

Balch, Clyde W., Toledo, Ohio

Barber, F. Taylor, Bartlesville, Okla.

Blaine, Edward A., Parma Heights, Ohio

Boulder, E. R., Riverside, Pa.

Bradshaw, George B., Jr., Charleston, W. Va.

Bradshaw, Joseph G., Glenshaw, Pa.

Buckley, Page S., Orange, Tex.

Calloway, Foster F., St. Albans, W. Va.

Calton, F. R., San Jose, Calif.

Chapman, Robert F., Phila., Pa.

Curran, Charles S., West Point, Pa.

DeLancey, Merton M., Charleston, W. Va.

Ellis, D. R., Jr., Ambler, Pa.

Eliot, Theodore Q., Tulsa, Okla.

Estes, Keith E., Oak Ridge, Tenn.

Evans, Chives W., Freeport, Tex.

Franz, R. J., Somerville, N. J.

Friedman, Julius, Detroit, Mich.

Getz, J. Warren, St. Albans, W. Va.

Goodmann, Eugene P., Whiting, Ind.

Hariu, Oscar H., Media, Pa.

Honeycutt, Earl M., Marcus Hook, Pa.

Jensen, J. Wallace, Torrance, Calif.

Jensen, Randolph A., Houston, Tex.

(Continued on page 68)



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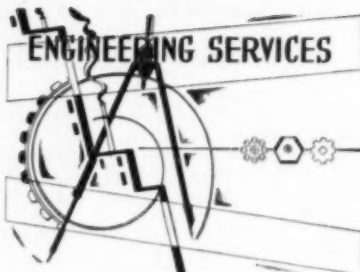
Kjellman, Harry A., Jr., Pittsburgh, Pa.  
Koplik, Myron John, New York, N. Y.  
Kuehler, Paul N., Baytown, Tex.  
Larson, Roger E., Schenectady, N. Y.  
Leisten, W. J., Wyandotte, Mich.  
Lunde, K. E., Stanford, Calif.  
Martz, Lyle E., Midland, Mich.  
Merrington, Robert S., New York, N. Y.  
Miller, Clarke C., Whiting, Ind.  
Miller, V. L. Keith, Corpus Christi, Tex.  
Morgan, Stanley L., Bedford, Ohio  
Omohundro, George A., Pittsburgh, Pa.  
Osmalov, Robert, Buffalo, N. Y.  
Pearce, F. G., Tulsa, Okla.  
Pond, Richard N., Rochester, N. Y.  
Ponder, Thomas C., Houston, Tex.  
Rahn, Richard C., Painesville, Ohio  
Ratcliff, Walter F., Aruba, N.W.J.  
Rice, R. W., Lake Charles, La.  
Rotzler, R. W., Texas City, Tex.  
Roudebush, Bert V., South Pasadena, Calif.  
Schneider, Paul H., Kingsport, Tenn.  
Schutze, Henry G., Baytown, Tex.  
Seyfried, W. D., Baytown, Tex.  
Stanfield, Zenas A., Wilson Dam, Ala.  
Strong, Charles E., Parlin, N. J.  
Thomas, C. Jack, Brandenburg, Ky.  
Tomkowiak, T. W., Penns Grove, N. J.  
Unger, Wm. E., Oak Ridge, Tenn.  
Walsh, Arthur G., Fort Worth, Tex.  
Winter, C. H., Jr., Wilmington, Del.  
Woodfield, F. W., Jr., Richland, Wash.

#### Applicants for Associate Membership

Chowdhry, Nazir A., Woolwich, London, S.E.  
Kalbach, Harold F., Wilmington, Del.  
Pekkala, Ralph O., Aiken, S. C.

#### Applicants for Junior Membership

Abernathy, Frank W., Kingsport, Tenn.  
Armistead, J. M., Port Arthur, Tex.  
Arneson, Eugene W., Greendale, Wisc.  
Awde, Jack E., Old Bridge, N. J.  
Babinsky, Theodore C., Buffalo, N. Y.  
Barnett, E. H., Jr., Lebanon, Mo.  
Batchelor, James D., Pittsburgh, Pa.  
Baumgartner, Jack A., New Orleans, La.  
Berenson, Conrad, Stamford, Conn.  
Eggers, E. W., Baytown, Tex.  
Bach, Louis G., W. Orange, N. J.  
Bowen, Robert L., College Park, Ga.  
Brown, Billings, Provo, Utah  
Brown, Dwight C., Waterford, N. Y.  
Butler, Neil E., E. Hartford, Conn.  
Campbell, Harvey A., Bishop, Tex.  
Cooper-Smith, Robert, Orange, Conn.  
Dailey, Charles E., III, Pittsburgh, Pa.  
DeLoache, George N., Aiken, S. C.  
Dickey, Knowles, New York, N. Y.  
Dudley, Ray, Jr., Baytown, Tex.  
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Eubank, Thomas D., Louisville, Ky.



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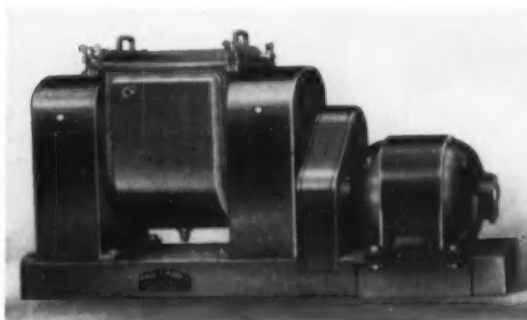
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Fujimoto, Mike S., Chicago, Ill.  
 Gabel, William F., Cincinnati, Ohio  
 Haaga, John C., St. Albans, W. Va.  
 Hardt, Harold A., Aiken, S. C.  
 Harvey, E. Malcolm, Baton Rouge, La.  
 Haury, Gerard L., Louisville, Ky.  
 Heine, Murray A., Hamden, Conn.  
 Herian, Robert W., Jr., West Chester, Pa.  
 Higgins, Edward Leray, Monterey Park, Calif.  
 Huddle, John G., Centerville Sta., Ill.  
 Hutchins, Leroi E., Crystal Lake, Ill.  
 Johnson, Adrian E., Jr., Beaumont, Tex.  
 Kaiser, Thurman W., Wilmington, Del.  
 Kelly, Arthur W., Jr., Charleston, W. Va.  
 Kerr, Arthur C., Port Arthur, Tex.  
 Knox, Ronald O., Fredericksburg, Va.  
 Kruse, William E., N. Augusta, S. C.  
 Lampe, Ross W., Kingsport, Tenn.  
 Lane, Samuel M., Richmond, Va.  
 Longstaff, Witt I., Kingsport, Tenn.  
 Lee, Chen Y., Trona, Calif.  
 Leyshon, David W., Westport, Conn.  
 Lubbers, Norman V., St. Louis, Mo.  
 Magill, William H., Alton, Ill.  
 Manes, Myron M., Grand Island, N. Y.  
 Marcus, Stanley A., Midland, Mich.  
 Marks, Allan F., Louisville, Ky.  
 Mazurek, Robert C., St. Louis, Mich.  
 McCauley, Fred D., Jr., Wilmington, Del.  
 Mittelberg, Roger F., N. Augusta, S. C.  
 Montfort, Jean A., Monroe La.  
 Nahabedian, Ardashes, Scott Air Force Base, Ill.  
 Newman, James B., Aiken, S. C.  
 Nienart, Louis F., Elizabeth, N. J.  
 Palm, Gordon F., Pasadena, Tex.  
 Peterson, Harold R., Riverton, Minn.  
 Peterson, Howard C., Newark, N. J.  
 Petretti, Richard V., Hingham, Mass.  
 Palk, Brian K., Akron, Ohio  
 Potter, John J., Jr., St. Albans, W. Va.  
 Price, Eugene B., White Plains, N. Y.  
 Purcell, James A., Augusta Ga.  
 Rich, Warren W., Wilmington, Del.  
 Rizzone, Angelo J., Woodbury N. J.  
 Roberts, William E., Akron, Ohio  
 Roos, John T., Denver, Colo.  
 Rosenbaum, Werner, New York, N. Y.  
 Rudy, Dennis D., Newark, Del.  
 Sailor, Robert Allen, Drexel Hill, Pa.  
 Savoy, Jacques L., Baton Rouge, La.  
 Segraves, Robert O., Alton, Ill.  
 Sells, Raymond H., Jr., Oak Ridge, Tenn.  
 Siefert, George J., Akron, Ohio  
 Snyder, Paul W., Jr., Swedesboro, N. J.  
 Szombathy, Louis H., Pearl River, N. Y.  
 Tallarico, Michael A., Tiltonsville, Ohio  
 Tennant, Bruce W., Whiting, Ind.  
 Tournour, Frank, New York, N. Y.  
 Turner, Andrew, So. Charleston, W. Va.  
 Unstead, Charles H., Kingsport, Tenn.  
 Van Ness, John H., Webster Groves, Mo.  
 Volz, Charles J. A., Pasadena, Md.  
 Walsh, Robert J., Dayton, Ohio  
 Weir, Clifford L., Brooklyn, N. Y.  
 Wikete, Peter, Jr., St. Louis, Mo.  
 Wilkinson, James A., Freeport, Tex.  
 Wong, James B., Park Forest, Ill.  
 Young, Thomas G., Augusta, Ga.  
 Youngblood, Gene M., Victoria, Tex.

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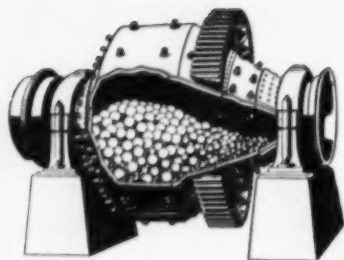
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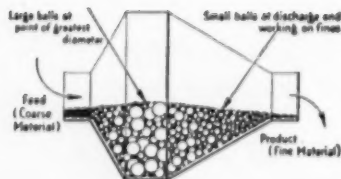
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# LOCAL SECTION NEWS



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The conical shape of the Hardinge Mill causes a rapid circulation and classifying action within the drum, which increases the capacity for power expended over other types. The range of grinding is large, due to the segregation of the sizes within the mill. The conical shape insures extreme rigidity and simplicity. Mechanical troubles are practically unknown. Sizes range from 2 feet to 10 feet with capacities from a few pounds per hour to 100 tons per hour. Bulletin 17-B-40 gives full details of dry grinding applications. Bulletin AH-389-40, wet grinding.



The Savannah River Chemical Engineers Club completed its organization with an election of officers at a meeting in Augusta, Ga., on Jan. 19, 1954. Bylaws had been adopted at the December meeting in Aiken, S. C. Officers elected to serve through 1954 are:

Chairman.....E. P. Foster  
Vice-Chairman.....John B. Roberts  
Secretary.....T. H. Crim  
Treasurer.....B. L. Baker  
Executive Committeemen: W. P. Bebbington, J. W. Morris, and P. S. Shane

H. H. Cudd, director of the Engineering Experimental Station, Georgia Institute of Technology, and a former chairman of the Atlanta Section, A.I.Ch.E., addressed the Club on "Science and Industry in the Southeast." At earlier meetings Thomas H. Chilton, of Du Pont Co., and former President of A.I.Ch.E., addressed the Club on "Why Is an Engineering Society?" and H. L. Greene, Du Pont's assistant plant manager of the Savannah River plant, spoke on the objectives and organization of a local section.

W. K. Stromquist, reporter, states that attendance over the period of organization has increased steadily from sixty-six to eighty-two.

N. W. Morley sent in a report on the Feb. 4 meeting of the Ohio Valley Section, which in cooperation with A.I.E.E., A.S.C.E., A.S.M.E., and The Engineering Society of Cincinnati, held a Professional Development Seminar at the Engineering Society Headquarters in Cincinnati, Ohio. The theme of the meeting was "The First Five Years of Professional Development." Cincinnati was chosen for the first meeting of a series to be held throughout the country by the Engineers Council for Professional Development on the above subject.

N. W. Morley also reported that on Jan. 20 the Section held a joint meeting with the American Society for Quality Control at the Engineering Society Headquarters in Cincinnati. The speaker for the meeting was James A. Mitchell, superintendent of development and control, Cellulose Esters Division, Tennessee Eastman Co., Kingsport, Tenn. Mr. Mitchell's subject was "Production Scale Experiments." In his talk he outlined how production experiments should be carefully planned and carried out in order to obtain results which can be statistically analyzed.

The present techniques and development of long-range weather forecasting were the subjects of a talk given by H. C. Willett, professor of meteorology at M.I.T., at the regular meeting of the Ichthyologists (Boston Section) on Jan. 22, 1954. His talk was followed by extensive discussion from the floor on weather forecasting in general. A. G. Smith reported the meeting. (See page 42 for announcement of symposium in Boston.)

The fifth annual all-day symposium of

the New Jersey Section will be held May 11, 1954, at the Essex House, Newark, N. J. Several reporters kept us informed of the forthcoming meeting. Details can be found in the News section on page 42.

Lauren Hitchcock, recently appointed president of the Southern California Air Pollution Foundation, discussed the chemical engineering aspects of the Los Angeles, Calif., smog problem at the March 16 meeting of the New York Section held at the Brass Rail.

At the January meeting 120 were in attendance to hear J. R. Hugill, of Canadian Liquid Air Co., Ltd., speak on low-temperature techniques. His talk, according to A. Jonnard, was a general survey of the various commercial applications of low-temperature technology, particularly the production of various high-purity gas streams such as ethylene, carbon monoxide, and ammonia synthesis gas.

The April 21 meeting will be a luncheon at which Morgan Sparks of Bell Telephone Laboratories will speak on transistors and their applications in the process industries.

The Jan. 26 meeting of the Cleveland Section was preceded by a dinner in the Oak Room at Fenn College. As first trial of the "brief biography" feature of this year's meetings, Bill Charbonnet, of Brush Laboratories, Bob Ingebo, of N.A.C.A., and R. R. Morse, of Sohio's Technical Service Division, reviewed briefly their company interests and their specific fields of activity.

W. D. Stillwell, director of field research of Harshaw Chemical for twenty years since receiving his doctorate from Western Reserve University, drew from his extensive experience in catalyst research, customer service, and new catalyst development to discuss the chemical and mechanical problems of catalyst preparation, specific catalysts and their application. D. J. Porter proudly reports that forty-five members and guests were present.

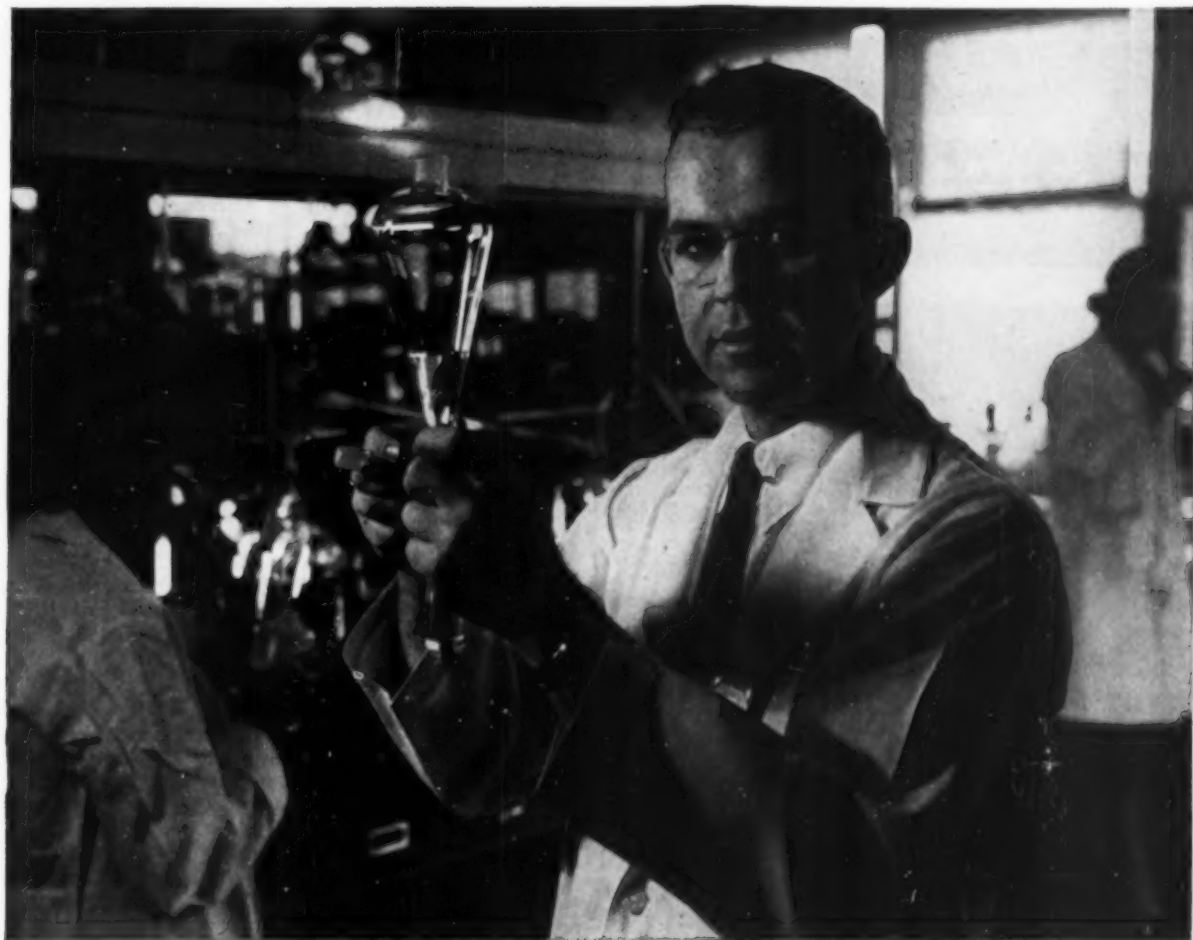
At the Feb. 15, 1954, meeting of the Northern California Section, Don Imhoff senior physicist, California Research & Development Co., gave a talk titled, "Northern California's First Atomic Reactor." His talk covered an explanation of the design and operating features of California Research & Development Co.'s atomic reactor at Livermore.

B. L. Lubin, reporter of Terre Haute Section, writes as follows:

The Terre Haute Section has taken on a new look. We are drifting away from strictly technical frictions to topics of more general interest. Local corporations are giving their support. Eatables and drinkables were supplied, respectively, by the Chas. Pfizer Corp. and the Commercial Solvents Corp. at two of the last three meetings. We plundered the local section treasury to pay for the third.

(Continued on page 73)





PHOTOGRAPH BY RICHARD BEATTIE

## What we still don't know about cancer —and one of the reasons why

IN THE PAST FEW YEARS, our knowledge of the nature of cancer, and how to treat it, has grown encouragingly. Patients, who would have been considered hopeless cases even five years ago, today are being completely cured. And even those who apply for treatment too late can usually live longer—and less painfully—because of modern palliative treatment.

All the same, there have been defeats as well as victories. We do not know—to take a single example—why so many more men are now dying from cancer of the lung. In 1933—just twenty years ago—lung cancer killed 2,252 men; in 1953, some 18,500. That's a great increase—which even our expanded population, and other known factors, can't possibly account for in full.

Well, why haven't we found more of the answers to cancer?

Not only because cancer is an im-

mensely complex problem; difficult to diagnose, and difficult to treat; challenging to the best research minds.

All that is true enough. But there is another reason: *we do not* have enough money.

Last year your gifts to the American Cancer Society were more generous than ever before. But they were not enough.

You gave the Society almost twenty millions to fight a disease that—at present death rates—will kill twenty-three million living Americans.

Less than one dollar for each American destined to die from cancer. Much more is needed for research, for education, for clinics. Won't you please do your part . . . now?

### American Cancer Society

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Man's cruellest  
enemy  
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## FUTURE MEETINGS AND SYMPOSIA OF A.I.Ch.E.

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Loren P. Scoville, Jefferson Chemical Company, Inc. 260 Madison Ave., New York 16, N. Y.

### Assistant Chairman

George Armistead, Jr., George Armistead & Co. 1200 18th St., N.W., Washington, D. C.

### MEETINGS

Springfield, Mass., Hotel Kimball, May 16-19, 1954.

Ann Arbor, Mich., Univ. of Mich., Ann Arbor, Mich., June 20-25, 1954—Conference on Nuclear Engineering.

TECHNICAL PROGRAM CHAIRMAN: D. L. Katz, Chairman, Dept. of Chem. and Met. Eng., Univ. of Mich., 2028 E. Eng. Bldg., Ann Arbor, Mich.

Glenwood Springs, Colo., Hotel Colorado, Sept. 12-15, 1954.

TECHNICAL PROGRAM CHAIRMAN: Dr. Charles H. Prien, Head, Chem. Div., Denver Res. Inst., Univ. of Denver, Denver 10, Colo.

Annual—New York, N. Y., Statler Hotel, Dec. 12-15, 1954.

TECHNICAL PROGRAM CHAIRMAN: G. T. Skaperdas, Assoc. Dir., Chem. Eng. Dept., M. W. Kellogg Co., 225 Broadway, N. Y. 7, N. Y.

ASST. CHAIRMAN: N. Morash, Titanium Div., National Lead Co., P. O. Box 58, South Amboy, N. J.

Louisville, Ky., Kentucky Hotel, March 20-23, 1955.

TECHNICAL PROGRAM CHAIRMAN: R. M. Reed, Tech. Dir., Gas Proc. Div., The Girdler Corp., Louisville 1, Ky.

Houston, Texas, Shamrock Hotel, May 1-4, 1955.

TECHNICAL PROGRAM CHAIRMAN: J. L. Franklin, Res. Assoc., Humble Oil & Refining Co., P. O. Box 1111, Baytown, Texas.

Lake Placid, N. Y., Lake Placid Club, Sept. 25-28, 1955.

TECHNICAL PROGRAM CHAIRMAN: L. J. Coulthurst, Chief, Proc. Designer, Foster Wheeler Corp., 165 Broadway, New York 6, N. Y.

Annual—Detroit, Mich.—Statler Hotel, Nov. 27-30, 1955.

TECHNICAL PROGRAM CHAIRMAN: T. J. Carron, Head, Chemical Tech. Office, Ethyl Corp., Res. Labs., 1600 West Eight Mile Road, Detroit 20, Mich.

Los Angeles, Calif., March, 1956.

TECHNICAL PROGRAM CHAIRMAN: T. Weaver, Proc. Eng., The Fluor Corp., Ltd., Box 7030, East L. A. Station, Los Angeles 22, Calif.

### SYMPOSIA

#### SYMPOSIA FOR SPRINGFIELD MEETING

##### Polymeric Materials of Construction

##### Process Design

##### Nuclear Engineering

CHAIRMAN: D. L. Katz, Chairman (Address: See Ann Arbor Meeting).

MEETING—Ann Arbor, Mich.

##### Agglomeration

CHAIRMAN: A. P. Weber, International Engineering, Inc., 15 Park Row, New York, N. Y.

MEETING—Glenwood Springs, Colo.

##### Uranium Processing and Refining

CHAIRMAN: R. H. Long, Vitro Eng. Div., Vitro Corp., 120 Wall St., New York, N. Y.

MEETING—Glenwood Springs, Colo.

##### Reaction Kinetics

CHAIRMAN: N. R. Amundson, Dept. of Chem. Eng., Univ. of Minnesota, Minneapolis 14, Minn.

MEETING—New York, N. Y.

##### Oil Shale and Shale Oil Processing

CHAIRMAN: W. I. R. Murphy, Pet. & Oil Shale Exp. Station, U. S. Bureau of Mines, P. O. Box 621, Laramie, Wyoming.

MEETING—Glenwood Springs, Colo.

##### Gas Absorption

CHAIRMAN: R. L. Pigford, Div. of Chem. Eng., Univ. of Delaware, Newark, Del.

MEETING—New York, N. Y.

##### Solvent Extraction

CHAIRMAN: Dr. R. B. Beckmann, Dept. Chem. Eng., Carnegie Inst. of Tech., Schenley Park, Pittsburgh 13, Pa.

MEETING—New York, N. Y.

##### New Processes Utilizing Moving Beds

CHAIRMAN: N. Morash, Tit. Div., National Lead Co., P. O. Box 58, South Amboy, N. J.

MEETING—New York, New York

##### Heat Transfer

CHAIRMAN: R. L. Pigford, Div. of Chem. Eng., Univ. of Delaware, Newark, Del.

MEETING—Louisville; Ky.

##### Nucleation Processes

CHAIRMAN: D. W. Oakley, Plant Mgr., Metal & Thermit Corp., 1 Union St., Carteret, N. J.

MEETING—Houston, Tex.

##### Centrifugation

CHAIRMAN: J. O. Maloney, Chairman, Dept. Chem. Eng., Univ. of Kansas, Lawrence, Kan.

##### Extraction of Hydrocarbons for Chemical Use from Pipe Line Gases

CHAIRMAN: E. E. Frye, J. F. Pritchard & Co., 210 W. 10th, Kansas City 5, Mo.

### Submitting Papers

Members and nonmembers of the A.I.Ch.E. who wish to present papers at scheduled meetings of the Institute should follow the following procedure.

First, write to the Secretary of the A.I.Ch.E., Mr. S. L. Tyler, American Institute of Chemical Engineers, 120 East 41st Street, New York, requesting three copies of the form "Proposal to Present a Paper Before the American Institute of Chemical Engineers." Complete these forms and send one copy to the Technical Program Chairman of the meeting for which the paper is intended, one copy to the Assistant Chairman of the A.I.Ch.E., Program Committee, address at the top of this page, and one copy to the Editor of Chemical Engineering Progress, Mr. F. J. Van Antwerpen, 120 East 41st Street, New York.

If you wish to present the paper at a particular symposium, one copy of the form should go to the Chairman of the symposium instead of the Technical Program Chairman of the meeting.

### Before Writing the Paper

Before beginning to write your paper you should obtain from the meeting Chairman, or from the office of the Secretary of the A.I.Ch.E., at 120 East 41st St., New York, a copy of the A.I.Ch.E. Guide to Authors, and Guide to Speakers. These cover the essentials required for submission of papers to the A.I.Ch.E. or its magazines.

### Copies of Manuscript

Five copies of each manuscript must be prepared. For meetings, one should be sent to the Chairman of the symposium, and one to the Technical Program Chairman of the meeting at which the symposium is scheduled. If no symposium is involved, the two copies should be sent to the Technical Program Chairman. The other copies should be sent to the Editor's office since manuscripts are automatically considered for publication in Chemical Engineering Progress, or the symposium series of Chemical Engineering Progress, but presentation at a meeting is no guarantee that they will be accepted.

### DEADLINE DATES FOR PAPERS

GLENWOOD SPRINGS MEETING—May 12, 1954

NEW YORK MEETING—August 12, 1954

LOUISVILLE MEETING—November 20, 1954

HOUSTON MEETING—January 1, 1955

LAKE PLACID MEETING—May 25, 1955

DETROIT MEETING—July 27, 1955

## LOCAL SECTION NEWS

(Terre Haute Section continued)

The January speaker was F. R. Carvell, head of development at the B. F. Goodrich Avon Lake Experimental Station. Topic was acrylonitrile, with discussions, demonstrations, and samples.

A minor change in local section policy was mentioned in Lubin's communication. Previously the section had taken student members from Rose Polytechnic Institute at a small annual-dues rate. The dues for students have now been eliminated. Previous relationship between the section and Rose Poly remains the same.

The first meeting for 1954 of the Tennessee Valley Section was held in Decatur, Feb. 24, at which Leighton D. Yates spoke on the history and development of fertilizers. Considered an expert on fertilizers, Mr. Yates is associated with the Tennessee Valley Authority. Raymond M. Albert, secretary of the section, reported the meeting.

### ONE-DAY MEETINGS

Boston Ichthyologists—April 14, Hancock Hall, M.I.T.

Philadelphia-Wilmington—April 27, University of Pennsylvania Museum, Philadelphia

New Jersey—May 11, Essex House, Newark

Two meetings were held in January by the Philadelphia-Wilmington Section. The first in Wilmington, attended by approximately seventy members, had as speaker W. E. Lushy, Jr., sales representative for titanium in the pigments department of Du Pont. Dr. Lushy discussed the manufacturing of titanium sponge, and the future as well as current applications, with particular reference to use in the chemical industry. The second meeting held in Philadelphia also was attended by seventy members. Francis Winn of Fractionation Research, Inc., spoke on applications of electronic computers to chemical engineering problems. W. E. Osborn, corresponding secretary of the section, again kept us informed of the activities of his section.

The second annual one-day meeting sponsored jointly by the Philadelphia-Wilmington Section of A.I.Ch.E. and the University of Pennsylvania will be held on April 27, 1954. Details of meeting on page 42.

The forty-second general meeting of the East Tennessee Section was held Feb. 8, at Tennessee Eastman Co. Twenty-nine members and six guests were present.

C. F. Paulson, a member of the Special Applications Department of the Permutit Co., spoke on "Applications of Ion Exchange." Mr. Paulson reviewed the basic types of ion-exchange media discussing the applications and performance of each.

(Continued on next page)

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**JUNIOR SIZE  
DRYER**



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(East Tennessee Section continued)

Officers elected for the new year are

Chairman.....R. O. Hubbard  
Vice-Chairman.....Carl Wilson  
Secretary-Treasurer.....M. L. Gernert  
Director (1954-57).....C. B. Mather

Toy F. Reid reported the meeting and concluded with the statement that a motion was carried that the local section boundaries include those counties which come within a radius of 60 miles of Kingsport.

At the Feb. 18 meeting of the Tulsa Section, J. E. McCarthy, district engineer, Clark Bros., gave a talk on the present picture of centrifugal compressors. Mr. McCarthy has had wide experience in the design and application of centrifugal compressors as used in petroleum refining and natural gas installations.

At the first dinner meeting of the year of El Dorado Section on Jan. 15, J. W. Moorman, consulting engineer from Tulsa, Okla., talked on fluid catalytic cracking. His discussion included the variables affecting catalyst flow and coke yield. In addition the latest developments in design and operation of the Model IV and the Orthoflow Units were described. Approximately fifty members and guests attended the meeting, says reporter O. A. Fuchs.

New officers of the Atlanta Section are as follows:

Chairman — Frederick Bellinger,  
Georgia Tech Engineering Experiment Station  
Vice-Chairman—B. B. Crocker,  
Monsanto Chemical Co.  
Secretary - Treasurer — Fred E. Rowe, Tennessee Corp.  
Executive Committee: E. M. Jones,  
Tennessee Copper Co.; Clyde P. Orr, Monsanto Chemical Co.; E. H. Conroy, Tennessee Corp.; Joseph E. Ross, Georgia Tech.

The honor guest at the installation meeting, the first of 1954, was Gustav Egloff, director of research, Universal Oil Products Co., Chicago, Ill. Dr. Egloff was introduced by Dr. Bellinger as "Mister Petroleum," a title popularly awarded him in recognition of his outstanding achievements in the field of petrochemical research. He described many products obtained indirectly from petroleum, including high purity benzene and toluene, the new synthetic polymer fibers, Dynel and Dacron, and plastics such as polyethylene and saran.

This was one of the best meetings and the largest in attendance with sixty-three present, says Reporter H. H. Sineath.

Gordon Henderson gave an illustrated talk titled, "Chemical Valley—Sarnia, Ontario," at the Feb. 3 meeting of the Detroit Section. Mr. Henderson has been active as an engineer in the Sarnia area since its birth as a chemical center, and is presently general manager of



the new Sun Oil refinery in Sarnia. Reporter D. W. Anderson promised more news for our next issue.

The Twin Cities Section held its first meeting of 1954 on Jan. 6, at the Curtis Hotel, Minneapolis. Speaker for the evening was Archie B. Japs, director of chemical engineering research, B. F. Goodrich Rubber Co. Mr. Japs' talk was concerned largely with the facilities for chemical engineering research at B. F. G. company. He also showed samples of some of the newer products in the late development stage. Arthur Madden, Jr., a new contributor to these columns, sent in this piece of news.

On Feb. 17, 1954, a meeting of the Rochester Section was held at the Rundel Memorial Library at which John Espy talked on "Problems of the Chemical Industry in Turkey."

Mr. Espy taught industrial chemistry at Robert College in Istanbul, Turkey, for six years. This is the nearest course to chemical engineering taught at Robert College.

William H. Ellinger and O. J. Britton report on this section's meetings.

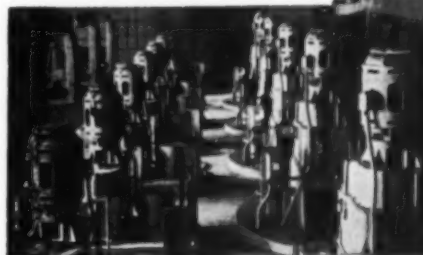
The Pittsburgh Section held its fifth dinner meeting of the 1953-54 year on Feb. 3 at the Sheraton Hotel in downtown Pittsburgh. The meeting was attended by approximately seventy local engineers and friends. The guest speaker of the evening, A. Letcher Jones, research supervisor of the Chemical and Physical Research Division, Standard Oil Company of Ohio, gave a talk entitled "Thermal Diffusion." Dr. Jones outlined the problems encountered in the thermal diffusion process, including the close tolerances needed in the design of the apparatus. He presented several binary and ternary solutions which have been separated by his laboratory's thermal diffusion apparatus. Among others, the speaker presented graphically the degree of separation brought about between solutions of *ortho* and *para*, and *ortho* and *meta* xylene. Messrs. Morrissey and Black, reporting the meeting, remarked that Dr. Jones concluded with a few observations on the costs involved in thermal diffusion.

At a recent meeting of Chicago Section held in Builders Club in downtown Chicago, 150 members and guests heard a discussion on crystallization by Hans Svanoe of Struthers-Wells Corp. The talk was illustrated with slides showing the effect of impurities and conditions on crystal structure.

The Northeastern New York Section held its monthly meeting in Schenectady on Feb. 9, 1954. Bryce MacDonald, chairman of the section's R.P.I. plan, reported that eleven lectures are scheduled for this semester. The lectures began Feb. 22 and will continue on Monday afternoons in the Rickets Building at Rensselaer Polytechnic Institute, Troy.

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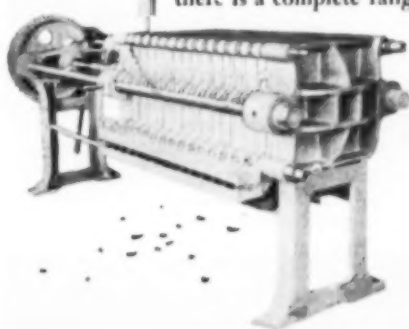
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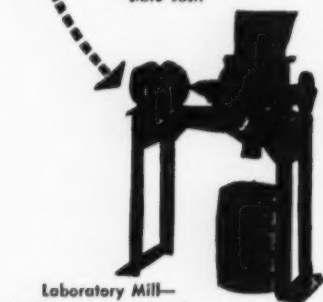
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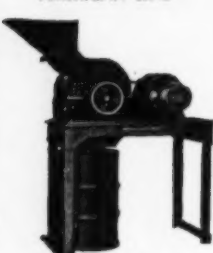
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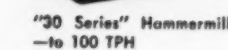
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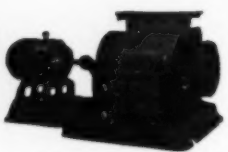
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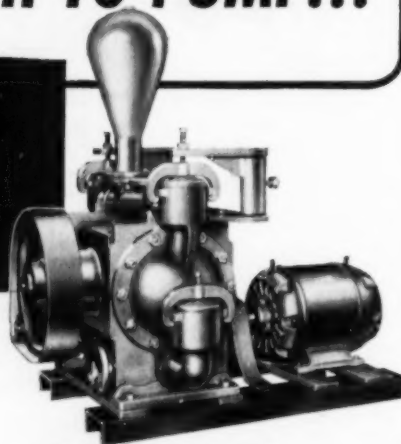
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H. L. Barnebey, president of the Chemical Processes Co., Pittsburgh, Pa., talked on "How Chemical Plants Are Born." He described some steps by which chemical plants come into existence. A. C. Schafer, Jr., reports that the talk "struck a responsive chord in the minds of all those present."

"Product and Processing Improvements in the Fiberglass Industry" was discussed by Clayton A. Smucker, technical personnel manager, Owens-Corning Fiberglass Corp., Newark, Ohio, at a dinner meeting of the Central Ohio Section held at the Faculty Club, Ohio State University, on Feb. 23. George F. Sachs, reporting the meeting, said that a previously scheduled address by Sherwood Fawcett, chief of engineering mechanics research, who was to have discussed "Engineering Problems in the Design of Nuclear Power Reactors," had to be postponed to a later date.

It was announced at the Feb. 18 meeting of the Rhode Island Section that Dr. Kinckiner, deputy director of the Engineering Research Laboratory of Du Pont Co., will be the speaker at the March meeting, and that C. G. Kirkbride, President of A.I.Ch.E., will attend the April meeting.

Roy G. Volkman, chief chemist of the Mechanical Goods Division of U. S. Rubber Co., Providence Division, gave a talk titled "Quality Control at U. S. Rubber Company." Reporter Morton Port said it was a thorough explanation of the use of statistical methods for controlling the quality of various items of manufacture.

The chairman noted that attempts to obtain a speaker on Atomic Energy were not successful mainly due to the necessity of security clearances.

Belated congratulations to a new-comer, the R. I. Section!

### CHEMICAL PROGRESS TOLD TO ENLISTED ENGINEERS

A recent meeting of the Enlisted Specialists Chemical Engineering Club of the Army Chemical Center, Md., featured a lecture-demonstration by Louis P. Shannon of the Du Pont Co., titled "Progress in Better Living." Mr. Shannon documented the story of American progress by exhibiting developments resulting from chemical research and explained how their production strengthened the national economy. Mr. Shannon also displayed some chemical developments which are still in the planning and experimentation stage and pointed out that research and development are vital to the growth of all types of American industry.

The Enlisted Specialists Club is comprised of inductees assigned to this post under the Army's Scientific and Professional Personnel program. These "soldier-scientists" are given the opportunity and encouraged to continue their professional careers.

H.R.G.

## PEOPLE

**Frank R. Ward**, formerly associated with Monsanto Chemical Co., DuPont Co., and the American Cyanamid Co., is now with the atomic power division of Westinghouse Electric Corp., Pittsburgh, Pa., as a project coordinator in the reactor and materials department. Since 1949 he has been on the staff of the division of reactor development, Atomic Energy Commission, Washington, D. C.



### FURNAS, CHAIRMAN OF NEW AERONAUTICS PANEL

**C. C. Furnas**, director of Cornell Aeronautical Laboratory, Inc., Buffalo, N. Y., has been appointed chairman of the recently formed Technical Advisory Panel on Aeronautics of the Department of Defense. He was formerly chairman of the Guided Missiles Committee of the Research and Development Board of the Department of Defense, which was replaced last year when an office of Assistant Secretary for Defense for Research and Development was established. The present Panel, composed of civilian scientists and experts, was formed to insure that the country's best technical talent is applied to planning and carrying out military research and development in aeronautics. At one time Dr. Furnas was also a member of the Committee for Aeronautics of Research and Development Board.

Dr. Furnas was a Director of A.I.Ch.E. (1945-47).

**Lauren B. Hitchcock**, who has been engaged for the past year in consulting practice in New York and was formerly president of the National Dairy Research Laboratories, Inc., has been named president of the Southern California Air Pollution Foundation. Aiming to find the



cause of smog and the best way to eliminate it, the Foundation selected a man experienced in research and development. Dr. Hitchcock served the Industrial Research Institute, Inc., New York, and for five years was vice-president in charge of the chemicals department in the development of furan chemicals. He was also associated with

Hooker Electrochemical Co., Niagara Falls, N. Y., and was given chemical research assignments while in the U. S. Army. Dr. Hitchcock was one of the founders of the Commercial Chemical Development Association.

**Shea Smith, III**, director of business research, Merrimac division, Monsanto Chemical Co., was recently appointed assistant director of marketing research for the company. Prior to his association with Monsanto, he was with the Arthur D. Little Co., Cambridge, Mass. He received his B.S. degree in chemical engineering at the University of Wisconsin in 1938 and his M.B.A. degree in 1941 from Harvard Business School.

The appointment of **Cortez P. Hackett** to the post of director of development, Solvay Process Division, Syracuse, N. Y., Allied Chemical & Dye Corp., recently was announced. A graduate of the Colorado School of Mines, Mr. Hackett has been with Solvay since 1923. Starting as an engineer he subsequently advanced to the positions of section supervisor, assistant chief engineer, chief engineer and assistant director of development. In his new post he heads engineering, research and construction departments of Solvay.

The appointment of **George Sarvadi, Jr.**, as design and development engineer



at Falls Industries, Inc., Cleveland, Ohio, has recently been announced. Prior to joining Falls Industries, he was associated with The Harshaw Chemical Co. as development engineer. He received his B.S. degree in chemical engineering from Illinois Institute of Technology and his M.S. degree in chemical engineering from Case Institute of Technology. During World War II he attended Columbia University under a Naval education program, after which he served a year at sea as a Midshipman.

**Christian J. Matthew**, according to an announcement by Earl P. Stevenson, president of Arthur D. Little, Inc., will be one of those in charge as an associate of its newly opened Western regional office in San Francisco. Mr. Matthew graduated from the Massachusetts Institute of Technology in chemical engineering in 1942. Since graduation he has been on the A. D. Little staff, where he has been active on projects involving both scientific and economic studies.



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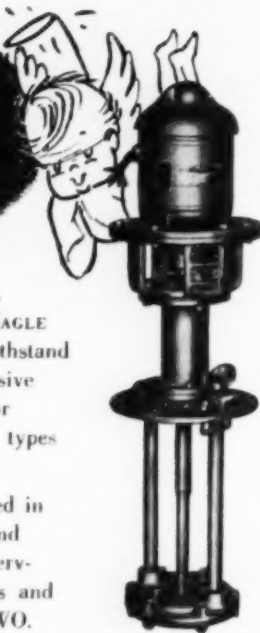
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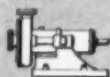
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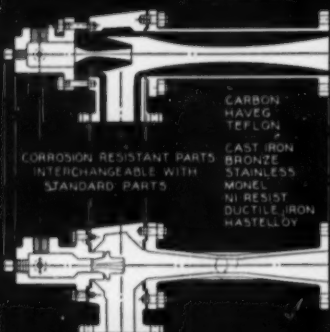
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**Malcolm M. Coston**, district chemical engineer for twelve years at Philadelphia and other points for the Swenson Evaporator division of the Whiting Corp., is now manager of the process equipment division of Rodney Hunt Machine Co., Orange, Mass. He will be responsible for the sales and development of Turba-Film Evaporator and the Rodney Hunt-Lawa Spray Dryer. He is a graduate of Alfred University and the University of Michigan with B.S., Ch.E. and M.S.Ch.E. degrees.

**W. M. Trigg** has been named manager of Westinghouse Electric Corp.'s new metals development plant which will be built at Blairsville, Pa. Mr. Trigg received his B.S. degree in chemical engineering from the University of Pittsburgh in 1936 and served with the Carnegie-Illinois Steel Corp. in a research capacity until 1946, when he joined Westinghouse at East Pittsburgh as senior engineer in materials engineering department. He was appointed manager of insulation application in 1947. Subsequently, he was named manager of magnetics and insulation engineering and, in 1952, manager of the materials pilot manufacturing department.

Nuodex Products Co., Inc., has recently announced the appointment of

**John Kilcullen** as manager of its Elizabeth, N. J., plant. Formerly chief process engineer, Mr. Kilcullen has been with the company for the past seven years. He graduated from Ursinus College with a B.S. degree

in chemistry in 1943, and has done graduate work in chemical engineering at Newark College of Engineering. During World War II he was a Lieutenant (JG) in the Amphibious Corps.

**Daniel Fried** is now technical supervisor of the Jersey City division of Peter J. Schweitzer, Inc. A graduate of the University of Rochester with a B.S. degree in chemical engineering, Mr. Fried was formerly employed by the Vitro Corporation of America.



## CHANGES ANNOUNCED AT AMERICAN CYANAMID

**Kenneth H. Klipstein**, formerly assistant general manager and head of the technical department of Calco Chemical Division, has been appointed general manager of the newly created research division of American Cyanamid Co. This division will be responsible for the operation of the Stamford Research Laboratories and will also supervise other research and development programs. Mr. Klipstein received his M.S. degree in chemistry from Princeton.



K. H. Klipstein

**A. R. Loosli** is now assistant general manager of the newly formed fine chemicals division. This division will operate the Princeton, N. J., plant (recently purchased from Heyden Chemical Co.) and will handle domestic sales of bulk antibiotics, bulk pharmaceuticals. Mr. Loosli attended the University of Idaho and obtained his B.S. degree in physical sciences from the University of Chicago.



A. R. Loosli

**A. B. Hettrick** was assigned to the new pigments division as assistant general manager. The division will handle the production and sale of titanium dioxide and other pigments formerly handled by the Calco Chemical Division. Because of this new division **R. C. Swain**, vice-president in charge of research and development, will be able to devote full time to general staff matters and to assist in the determination of company policy.



A. B. Hettrick



R. C. Swain

(More News About People on page 81)

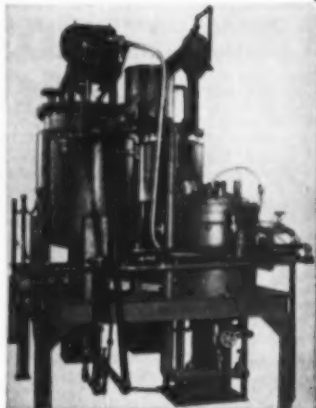
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**CHEMICAL ENGINEER—PRODUCTION MANAGEMENT**—Age 36. M.Ch.E. Twelve years' experience includes resident manager of alcohol plant; chief engineer of eight plant organization; assistant to vice president in charge of production. Seeking responsible position in production, management or plant engineering. Box 2-3.

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**CHEMICAL ENGINEER—MANAGEMENT**—Cornell 1943, Alexander Hamilton Institute. One employer affiliation since graduation; assistant to president, manager research and development department, sales engineer, petroleum refinery engineer, pilot-plant supervisor in reverse order. Credit manager and chemical operator prior to graduation. Present salary \$12,400. Age 34, married, three children. Seek connection with chemical or petrochemical manufacturer. Line or staff work in manufacturing, operations planning or economics. Outstanding references. Box 4-3.

**CHEMICAL ENGINEER**—B.S.Ch.E. 1948. Age 29, single. Five years' experience process design, piping, methods and planning, plant start-up, field construction. Desire sales engineering or process design in refining field. Willing to travel. Box 6-3.

**CHEMICAL ENGINEER**—M.Ch.E. Twelve years' experience process development in petroleum refinery equipment, catalytic cracking processes, oxygen plant development, ammonia synthesis. Age 31; fourteen publications. Desire responsible position in research administration or management. Box 7-3.

**DEVELOPMENT ENGINEER**—B.Ch.E., 1942. Experienced in technical and economic evaluations, process development and improvement, pilot plant and laboratory supervision. Active member A.I.Ch.E. Desire challenging position. Eastern seaboard. Box 8-3.

**EXECUTIVE CHEMICAL ENGINEER**—Licensed, employed. Twenty years: administration, research, development, planning, economic evaluations. Commercial processes: petrochemicals, inorganics; patents; publications. Can make major contributions to your technical and economic growth. Retainer basis or possibly as full-time employee. Box 9-3, Chemical Engineering Progress.

**CHEMICAL ENGINEER**—B.S. 1952. Age 24, married. Will be available in May after release from the Army. Some experience in the production of smokeless powder. Desire position in process development or production. Prefer West Coast or Western location. Box 12-3.

**FERTILIZER**—Chemical engineer well grounded in fertilizer technology and experienced in production of granular fertilizers. Desire position in management or technical director of fertilizer company. Will consider technical service or sales. Box 13-3.

**INDUSTRIAL WASTES ENGINEER**—Age 36, excellent training, graduate degrees, honors. Thirteen years' experience in effluent disposal field, last eight in industry. Research publications, committee appointments. Speak and write well. Seek responsible position with future. Box 14-3.

**PLANT MANAGER**—Chemical engineer, qualified by twenty years' experience to direct production and allied activities in processing company including engineering, personnel, safety, manufacturing, and quality control. Good at cost reduction programs. Three patents granted. M.I.T. graduate. Age 43. Box 15-3.

**CHEMICAL ENGINEER**—Age 27, M.S., M.I.T. Desire position abroad or with travel in production-development or technical sales. Over two years' experience in first, two in second. Have traveled extensively. Know perfectly French, Spanish; also Portuguese, Italian, Dutch, German. Box 16-3.

The appointment of **William F. Scanlan** as chemical sales engineer for the Swenson Division, Whiting Corp., at Ardmore, Pa., was recently announced. After graduation in 1945 from Purdue University, he joined Swenson Evaporator Co., division of Whiting, and after several years' experience on engineering, sales, and operating assignments in both the chemical and paper pulp departments, he was assigned to the Houston, Texas, district office as chemical sales engineer.



**David M. Williamson** is now area manager of industrial sales for the Baldwin-Hill Co., Huntington, Ind., manufacturers of thermal insulation. Mr. Williamson has been with the company as district manager for over six years and prior to his affiliation with this company he was production manager, Western division, Monsanto Chemical Co.

**J. S. Rearick** has joined The C. W. Nofsinger Co., engineers & contractors of Kansas City, Mo., as manager of engineering. Previously he was with The M. W. Kellogg Co. for more than sixteen years as associate director of research, development engineer and division engineer. He was closely associated with the development of hydroforming, fluid catalytic cracking, and various other petroleum and chemical processes.

**Charles T. Cross**, previously with General Motors Corp., Detroit, Mich., is

now with the patent department of Diamond Alkali Co., Painesville, Ohio, as a patent attorney.

Atlas Powder Co. recently announced that **James B. Weaver** has been added to the firm's planning department. Mr. Weaver was techno-economist and staff section chief in research for Olin Industries, Inc., for the past four years. Prior to that he was assistant to the director of research and development for Godfrey L. Cabot, Inc., and a teaching assistant at Massachusetts Institute of Technology.

**N. B. Galluzzo** is presently associated with Monsanto-Boussois, S. A., in the capacity of plant director, a position corresponding to plant manager. This is an associated company of Monsanto formed for the manufacture of polystyrene plastics in France. Prior to this association he held various supervisory assignments in the operating departments of Monsanto Chemical Company's plastics division plant at Springfield, Mass. In 1952 he was in Europe for several months as a member of a startup team to commission a plastics plant in Italy.

**Howard Louis**, formerly project chemist in the technical division, American Viscose Corp., is now technical adviser to the acid department at the Marcus Hook, Pa., plant. This department is responsible for the preparation and distribution of the acid spin bath used in the viscose-rayon process, reclamation of spent acid, and disposal of waste acid. Mr. Louis received his B.Ch.E. degree from The Cooper Union School of Engineering, and is doing graduate work at Drexel Institute of Technology.

**CHEMICAL ENGINEER**—B.S. 1946. Alexander Hamilton Institute. Five years control and research in fats and oils, 1½ in resin and rubber abrasive products development. Desire challenging opportunity in products development and evaluation. Married, one child. Salary \$7,000. Box 17-3.

**CHEMICAL ENGINEER**—Ph.D. Age 37. Fifteen years' experience industrial research, process development, organic and inorganic in several fields. Interested in coordination of research, laboratory or group head, technical service, or company liaison activity. Box 18-3.

**ENGINEER—BUSINESS ADMINISTRATION**—B.S. chemical engineering 1949, Master's degree in business administration 1954. Development and plant engineering, three years; product-cost estimating, two years. Personable, will travel. Desire market research or technical economics. Box 19-3.

**CHEMICAL ENGINEER**—B.Ch.E. 1951. Age 26, veteran, married. Graduate work toward M.Ch.E. Three years' experience includes pilot plant design and operation, process evaluations, cost estimating. Desire challenging position with future. Metropolitan area preferred. Box 20-3.

**MAN WITH EXECUTIVE ABILITIES**—Seeks challenging position with opportunity to prove his worth. This 33 year old chemical engineer (with Ph.D.) has had administrative, industrial, research and teaching experience. Box 21-3.

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#### Nonmembers

**CHEMICAL ENGINEER**—B.A.Sc. (honors) 1950, P.E. Age 32, married, veteran. Four years process development, control and supervision in cellulose products, lacquer formulation and solvent recovery. Desire responsible position preferably in development or control. Box 22-3.

**SALES ENGINEERING OR TECHNICAL SERVICE**—B.S.Ch.E. Carnegie Tech. M.S. industrial management University of Pittsburgh. Seven years management and production experience in chemicals and non-ferrous metals. Desire association with manufacturer's representative or similar. Box 23-3.

#### PLANT ENGINEERS PREFER

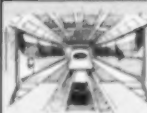
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The appointment of **Robert L. Parrish** as manager of the new plant of the Sprague Electric Co., now under construction at West Jefferson, N. C., has been announced. Mr. Parrish, who has been associated with the main plants of the company at North Adams, was formerly senior chemical engineer with Abbott Laboratories, North Chicago, Ill. He graduated from Georgia Institute of Technology and received his master's degree in chemical engineering from the University of Tennessee.

**Raymond B. Seymour**, executive vice-president and a member of the board of directors of the Atlas Mineral Products Co., Mertztown, Pa., since 1949, has been appointed president. The originator of furan cements and other products of the Atlas line, Dr. Seymour becomes the third president of this firm.

At one time Dr. Seymour was a research group leader at Monsanto Chemical Co., a director of the Industrial Research Institute of the University of Chattanooga, and director of special products research, Johnson & Johnson. He has also been associated with Good-year Tire & Rubber Co. as a plastics research chemist.

Dr. Seymour was chairman of the committee chosen by the American Electro-Chemical Society to write a supplement to the "Corrosion Handbook" on plastics and was co-compiler of the Plastics Equipment Reference Sheet, which appeared in many issues of C.E.P.

The new assistant sales manager of the Brosites Machine Co., Inc., and Brosites Products Corp., New York, is **Clarence E. Avery, Jr.** Mr. Avery was previously with Patterson Foundry and Machine Co., and just recently with The Pfaudler Co. as sales engineer in the New York office. Mr. Avery is a graduate of the New York University Graduate School of Business Administration, and has a chemical engineering degree from University of Rochester.

**Howard F. Roderick**, formerly director of sales for Michigan Alkali

Division, Wyandotte Chemicals Corp., and recently elected a vice-president of International Minerals & Chemical Corp., Chicago, Ill., will head the new Phosphate Chemicals Division of that company. Mr. Roderick joined Wyandotte Chemicals in 1931, after graduating from the University of Michigan. With that company he has been, successively, a chemist, director of research, director of research and market research, manager of chlorine and calcium carbonate sales, manager of chlorine, calcium carbonate and organic chemicals, and director of sales.

**Martin Buck**, formerly manager of manufacturing engineering, has been appointed assistant to the vice-president in charge of manufacturing, Shell Chemical Corp., New York. He joined the company as a chemical engineer at Wood River in 1930 and has also served at St. Louis and San Francisco.

## Necrology

### C. L. PARSONS

Charles Lathrop Parsons, a prominent figure in the chemical field for the past half-century, died in Pocasset, Mass., Feb. 13. He was 86 years old.

Secretary of the American Chemical Society from 1907 to 1945, and one of the organizers of the Chemical Warfare Section of the Army in World War I, he served also on the Nitrate Commission and the Advisory Board on Gas Warfare and was chairman of committee on use of zirconium in light armor.

Dr. Parsons was appointed chief of the bureau of mineral technology in the Bureau of Mines in 1911, and became chief chemist in 1916, continuing in that capacity until 1919.

Dr. Parsons, New Englander by birth, was graduated from Cornell in 1888 and received honorary degrees from the universities of Maine, New Hampshire, and Pittsburgh. At New Hampshire College, now the University of New Hampshire, he taught for more than twenty years.

As mentioned in C.E.P. (January, 1953, page 60), Dr. Parsons was awarded several honors for his public service and contributions to science, reference being made especially to his research on the atomic weight of beryllium.

### W. B. NEWKIRK

C.E.P. has recently heard of the death of W. B. Newkirk, retired. A graduate of the University of Southern California, with an B.A. in chemistry, Mr. Newkirk was associated for many years with the Corn Products Refining Co., Argon, Ill., serving in several capacities including the assistantship to the vice-president in charge of development.



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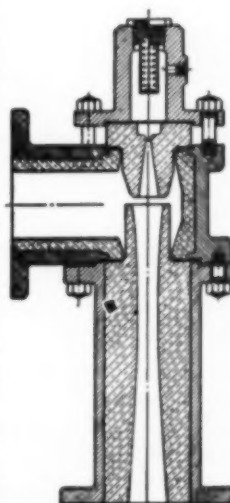
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# A.I.Ch.E.

## NEWS AND NOTES

Council's first action at each meeting is to approve the interim decisions of the Executive Committee, one of the many working groups helping the Institute to function.

According to the Constitution, Council "shall have supervision and care of all property of the Institute and shall transact all business of the Institute for it and on its behalf."

Such a task for the members of Council would prove impossible; so the actual labor involved is delegated to an Executive Secretary & staff & Institute committees.

Policy then becomes the major concern of Council, & more & more it deliberates on the broader aspects of the problems of the profession.

Routine items however must be approved by either Council or interim authority delegated to a committee.

Chief instrument of Council in this respect is the Executive Committee, composed of the President as chairman (Kirkbride), the Vice-President as v-chairman (Dodge), the Treasurer (Brown), the Secretary (Tyler) & the most recent past president (Nichols).

For instance, acting for Council, the committee last month accepted the Treasurer's report, elected to membership those applicants favorably acted on by the members, elected student members, & approved the formation of a student chapter at University of Massachusetts. On the recommendation of D. E. Holcomb, chairman of the Student Chapters Committee, the Executive Committee appointed D. L. Green, J. Salamone, & B. E. Lauer chapter counselors at Clarkson School of Technology, Newark College of Engineering, & the University of Colorado respectively.

Ann Arbor meeting this year is receiving much attention; theme of the meeting is Atoms for Peace.

News stories & editorial in the New York Herald Tribune hail the meeting as an important step to aid the Eisenhower plan to foster nuclear energy for peaceful purposes.

Problem of publicizing innovations in science and engineering is not new to the Institute, which has had a public relations committee since 1930. Current chairman is George Jenkins, & working under him is one of the Institute's largest & most active committees.

Internal communications to members as well as publicity about chemical engineering is the group's task. Internal public relations is usually investigated & pushed ahead by special committee projects. This page is the result of a drive by the committee for a news letter to all members.

Booklet "Know Your Institute," written several years ago & sent to every member, is now being revised by Ted Burtis.

Recent questionnaire was also the result of the Public Relations Committee's desire to know more about membership attitudes.

Dissatisfaction in the committee with Institute information services is healthy and continuous.

Committee suggested Council send two copies of all committee reports to local section chairmen as way of keeping members informed.

Also: stewed over a popular article for a national magazine to tell about chemical engineering; reported on attempts to get a special stamp for the Institute's 50th anniversary, planned a symposium on social responsibilities of engineers, appointed W. F. Kaiser to chairman a study on internal communications & lots more.

This is one example of why officers & staff of the Institute sincerely pay tribute to the work, imagination, & energy of committees.

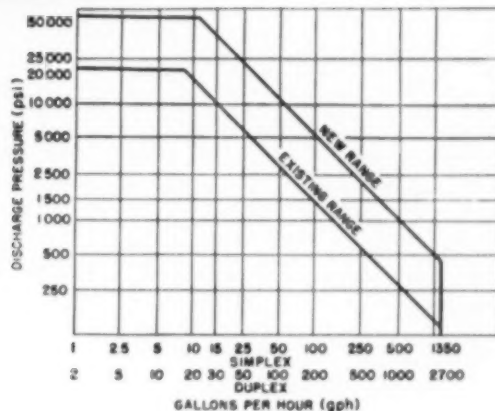
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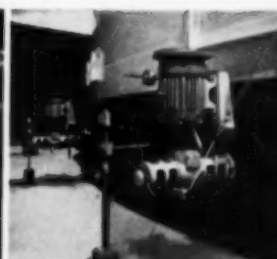
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